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Imran

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(54) **SYSTEM AND METHOD FOR ENHANCING SPEECH OF A DIVER WEARING A MOUTHPIECE**

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(51) **Int. Cl.**

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G10L 21/0364	(2013.01)
B63C 11/26	(2006.01)
H04B 11/00	(2006.01)
G10L 13/00	(2006.01)

(52) **U.S. Cl.**

CPC ***H04B 13/02*** (2013.01); ***G10L 21/0364*** (2013.01); *G10L 2021/03643* (2013.01); ***B63C 11/26*** (2013.01); ***H04B 11/00*** (2013.01); *G10L 13/00* (2013.01)

(58) **Field of Classification Search**

USPC 367/132; 340/850

See application file for complete search history.

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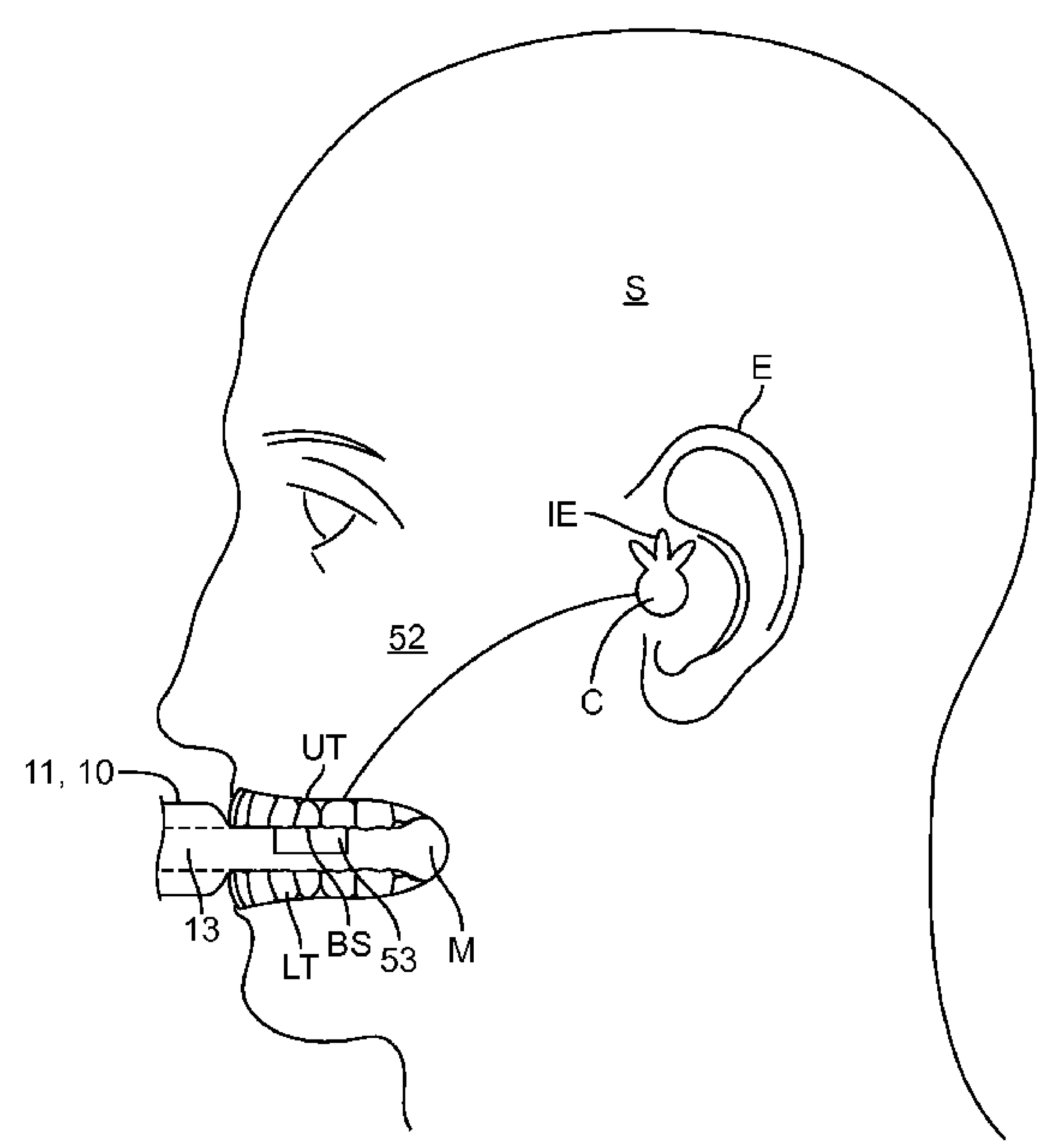
(57) **ABSTRACT**

Embodiments described herein provide a system, apparatus and methods to enable a diver to communicate more clearly with other divers or locations Embodiments process the speech to add clarity, or otherwise convert speech into an outputted form that is more intelligible e.g. so as to simulate the diver's unhindered speech. Embodiments provide hardware and software for receiving and recognizing hindered speech of a diver (e.g., speech hindered by a mouthpiece) and then augmenting the speech with generated output sounds corresponding to the intended speech sound or generating or replacing at least some of the diver's speech with synthesized words. The output sounds may be in the speaker's own voice or a synthesized voice. Embodiments may be configured to add clarity to and/or augment speech that is hindered by the wearing of a mouthpiece from a snorkel, SCUBA or other diving apparatus.

10 Claims, 17 Drawing Sheets



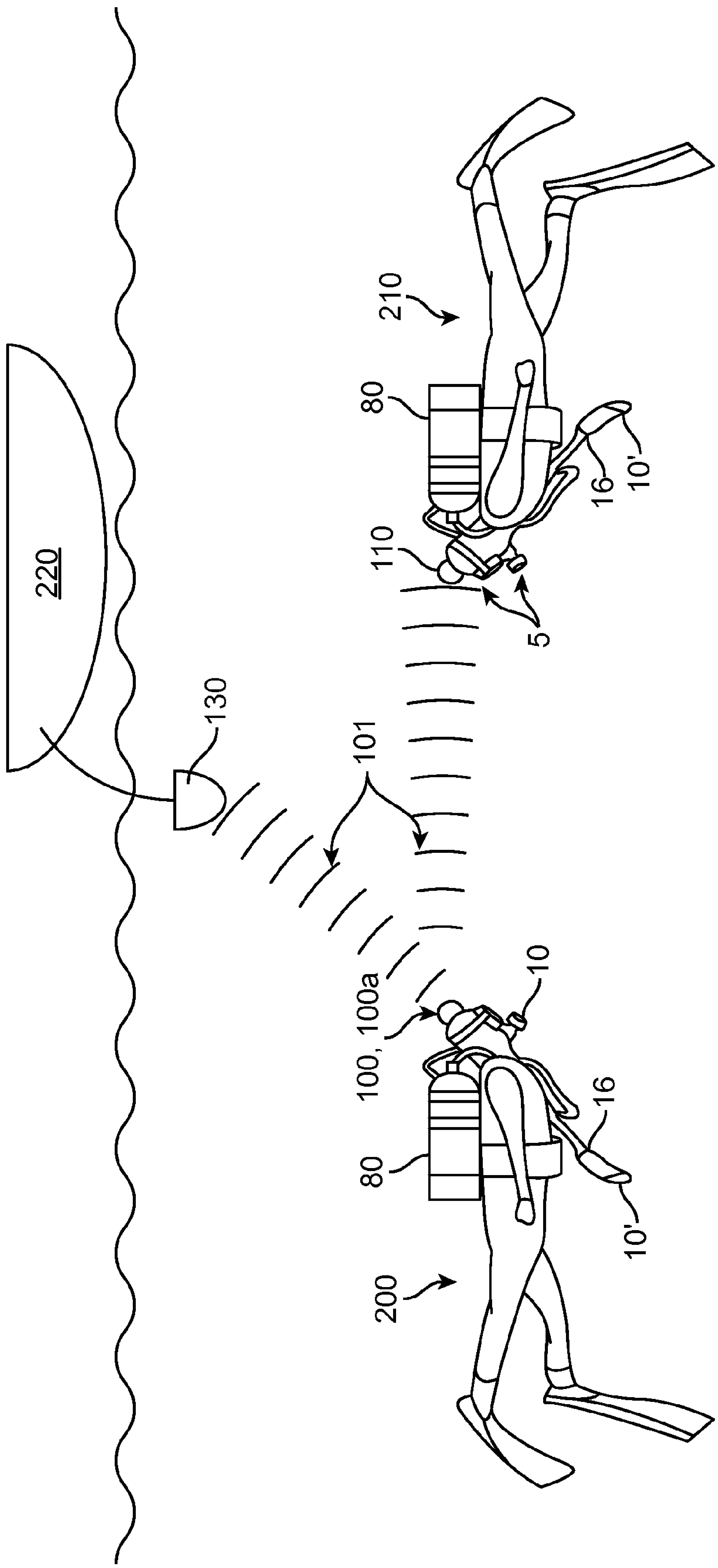


FIG. 1

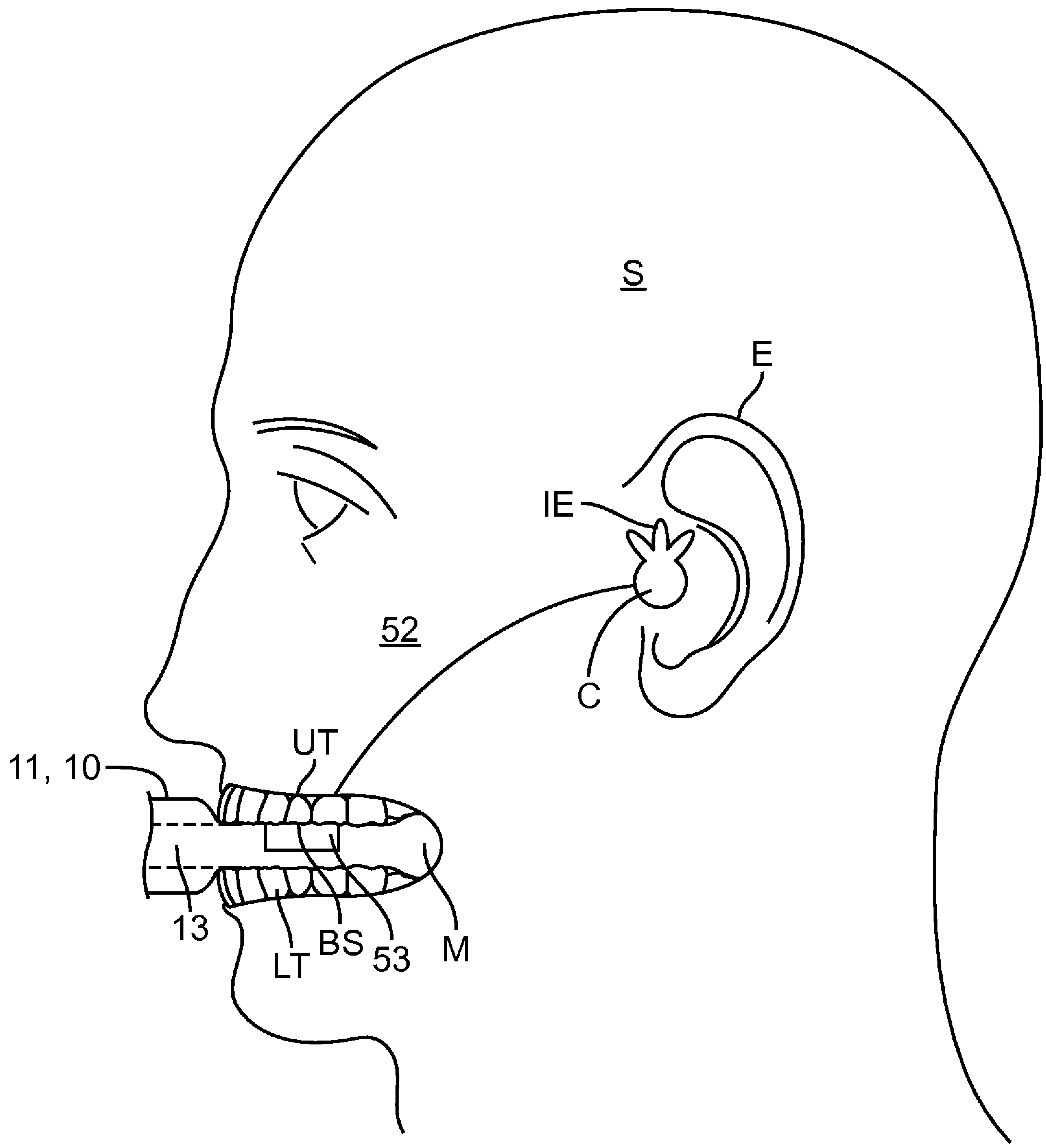


FIG. 1a

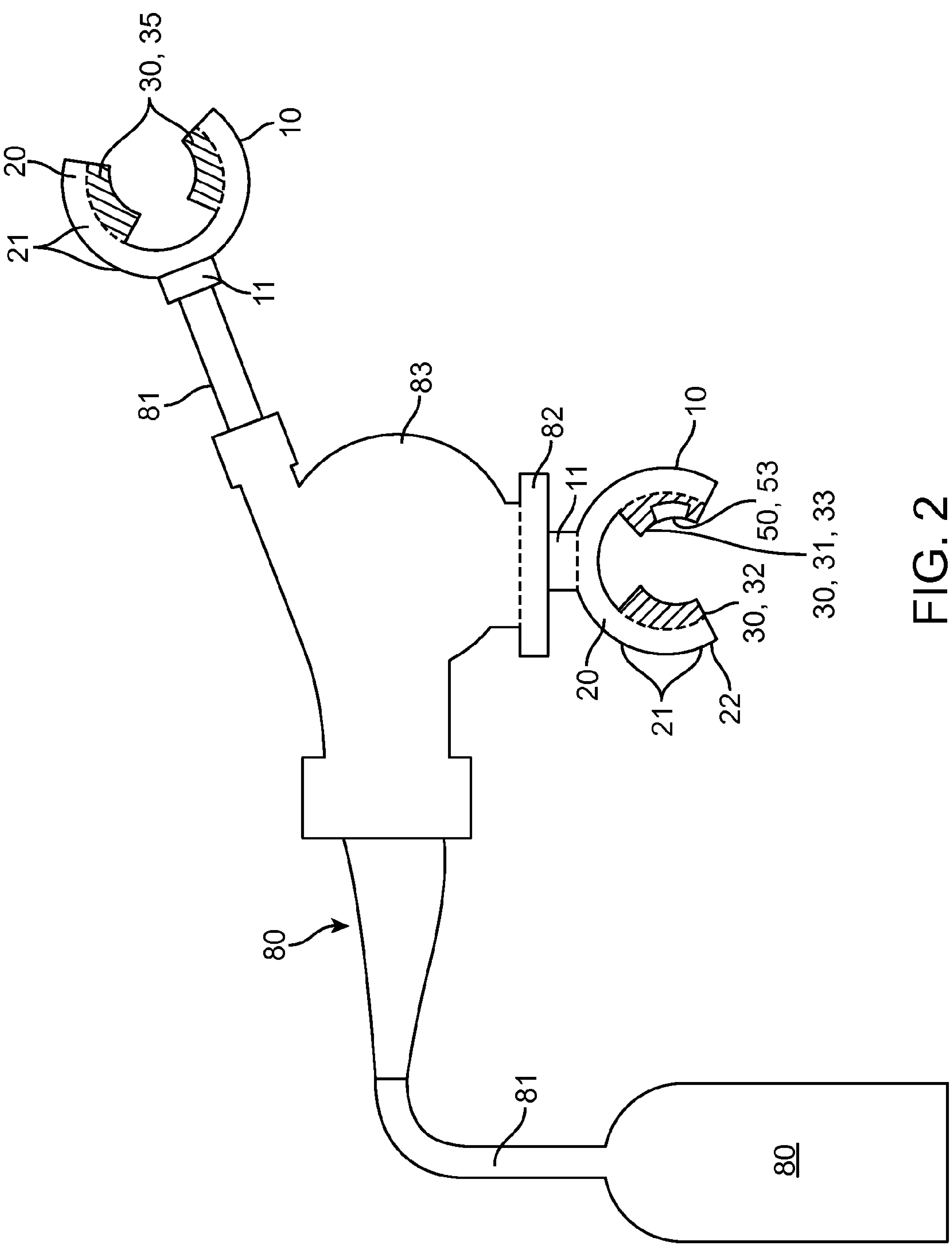
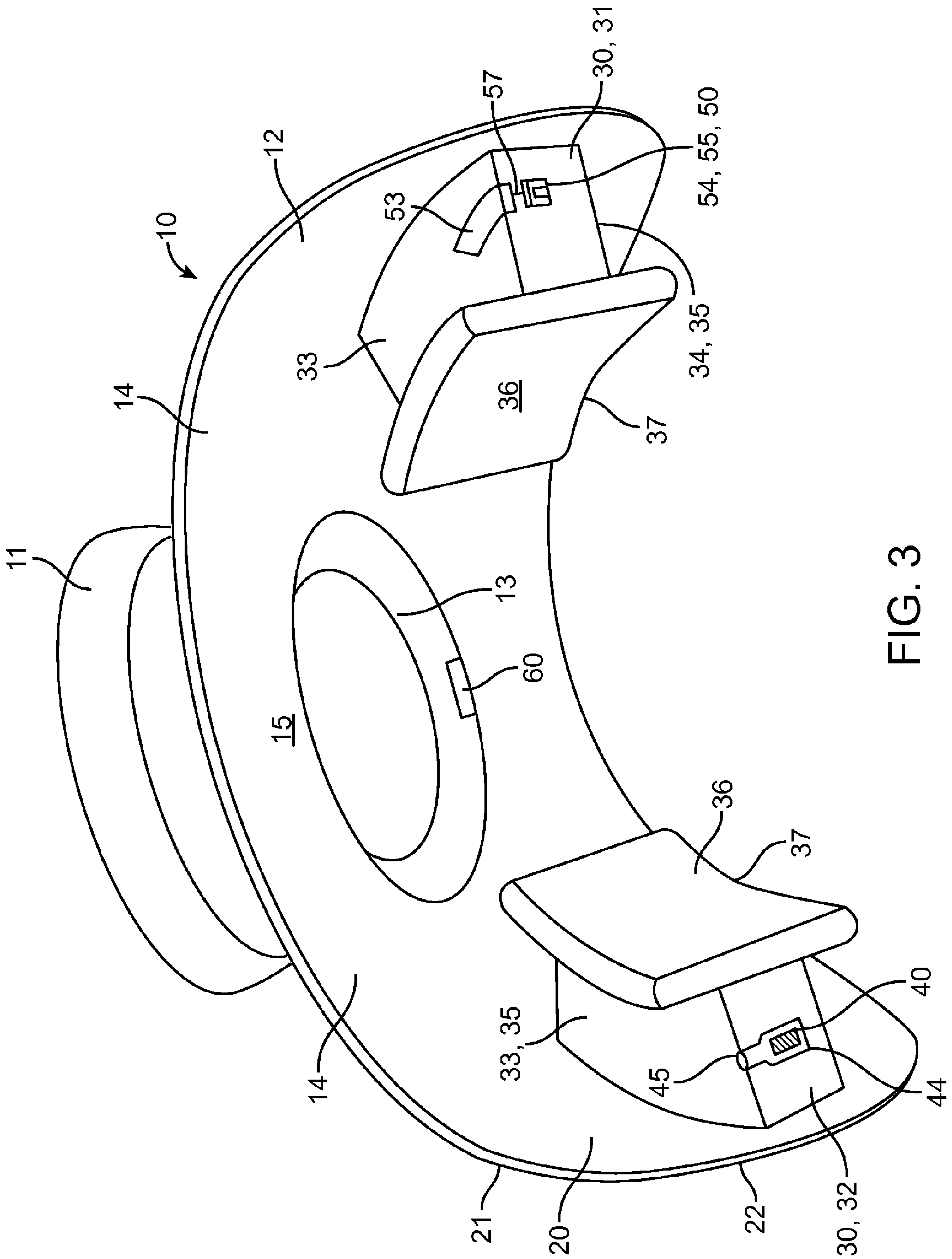


FIG. 2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54, 55, 50
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FIG. 3

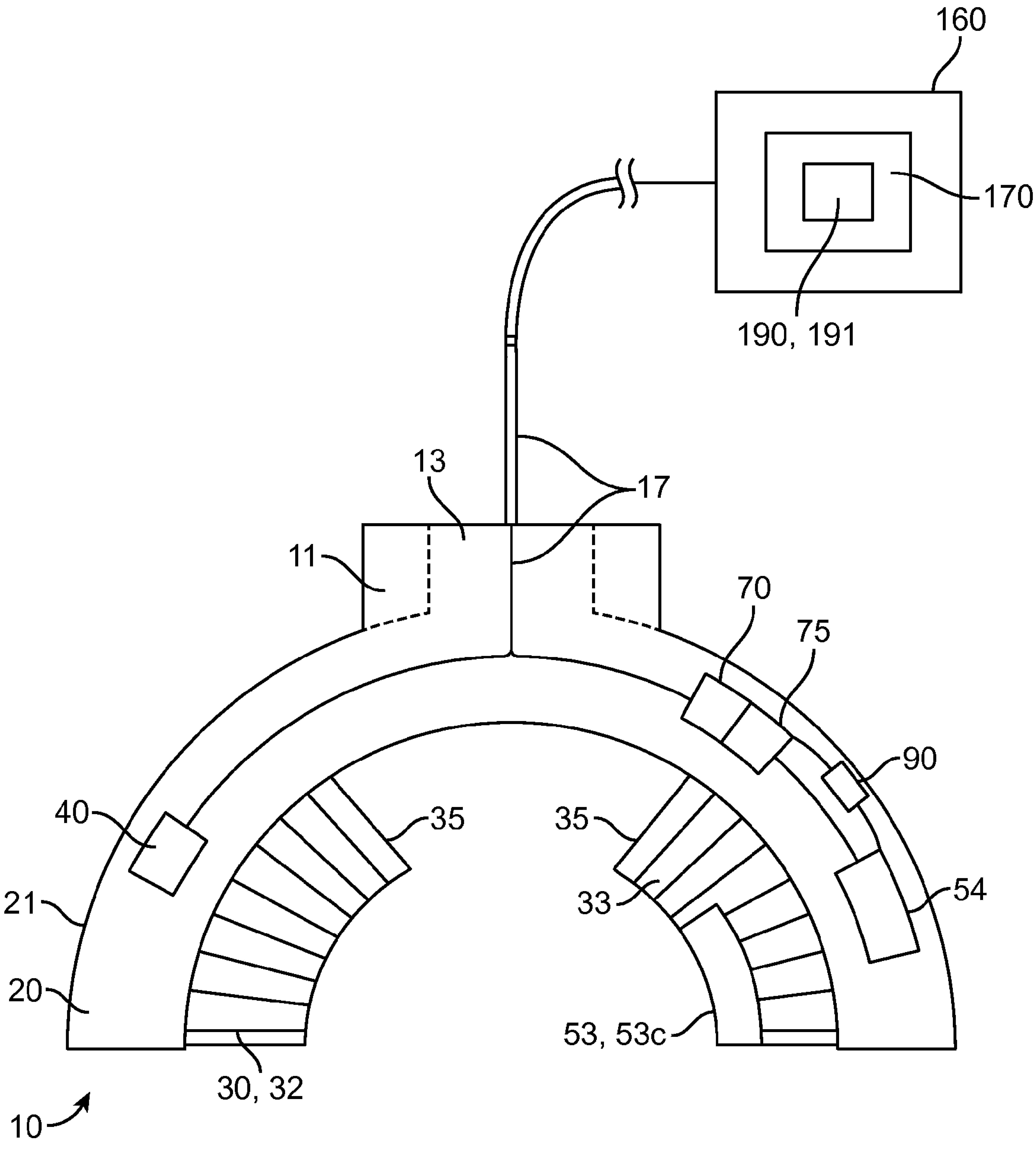


FIG. 4

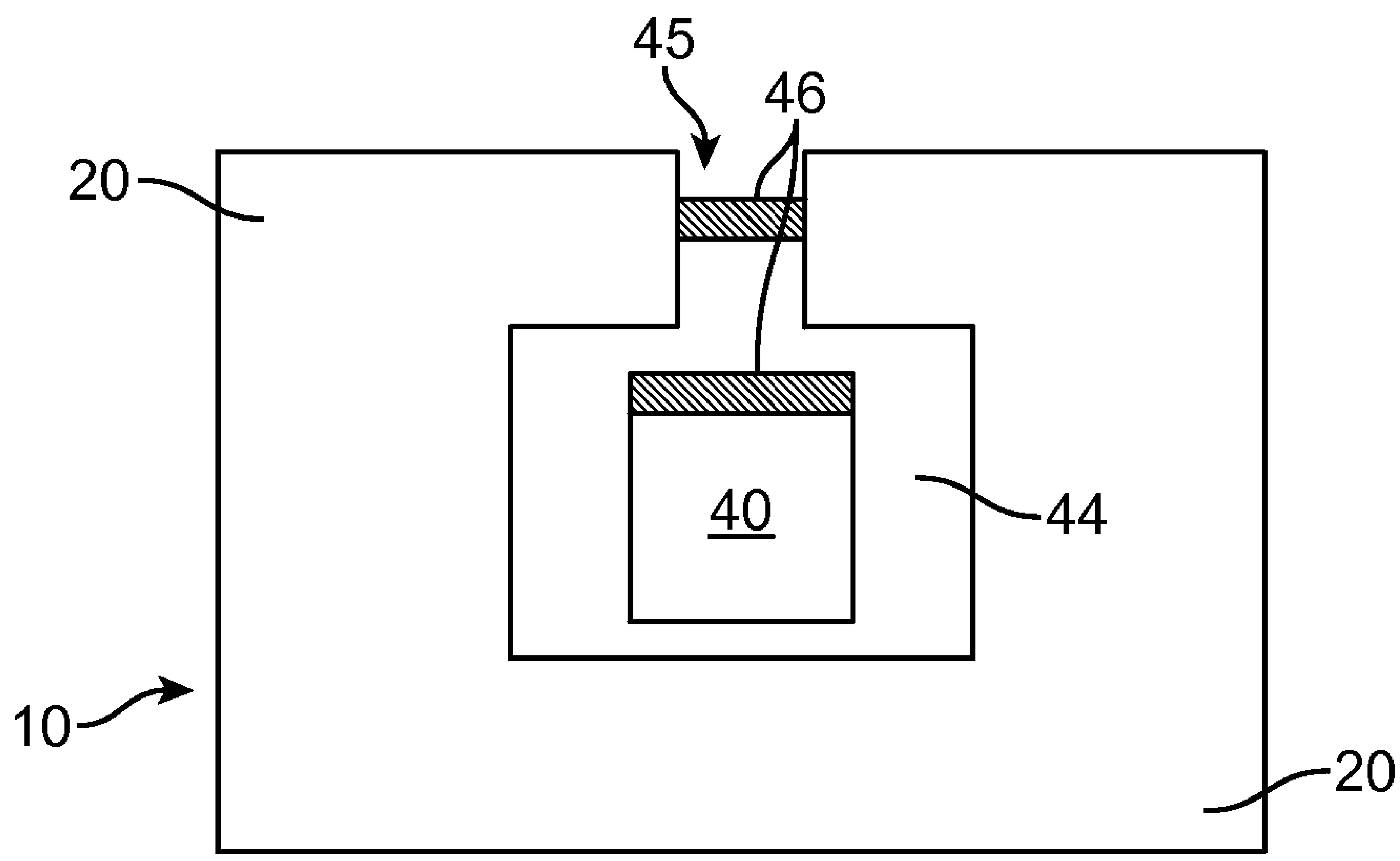


FIG. 5a

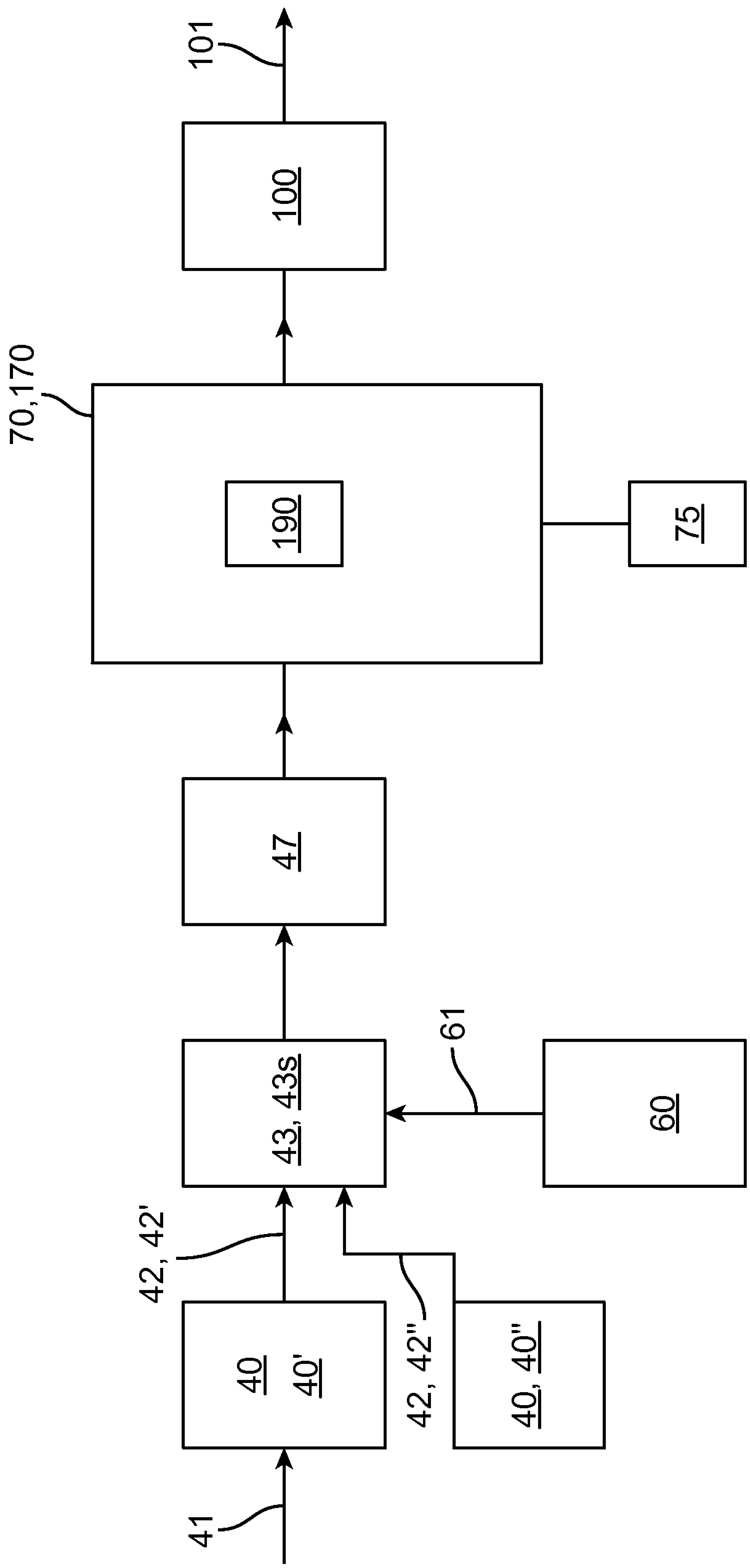


FIG. 5b

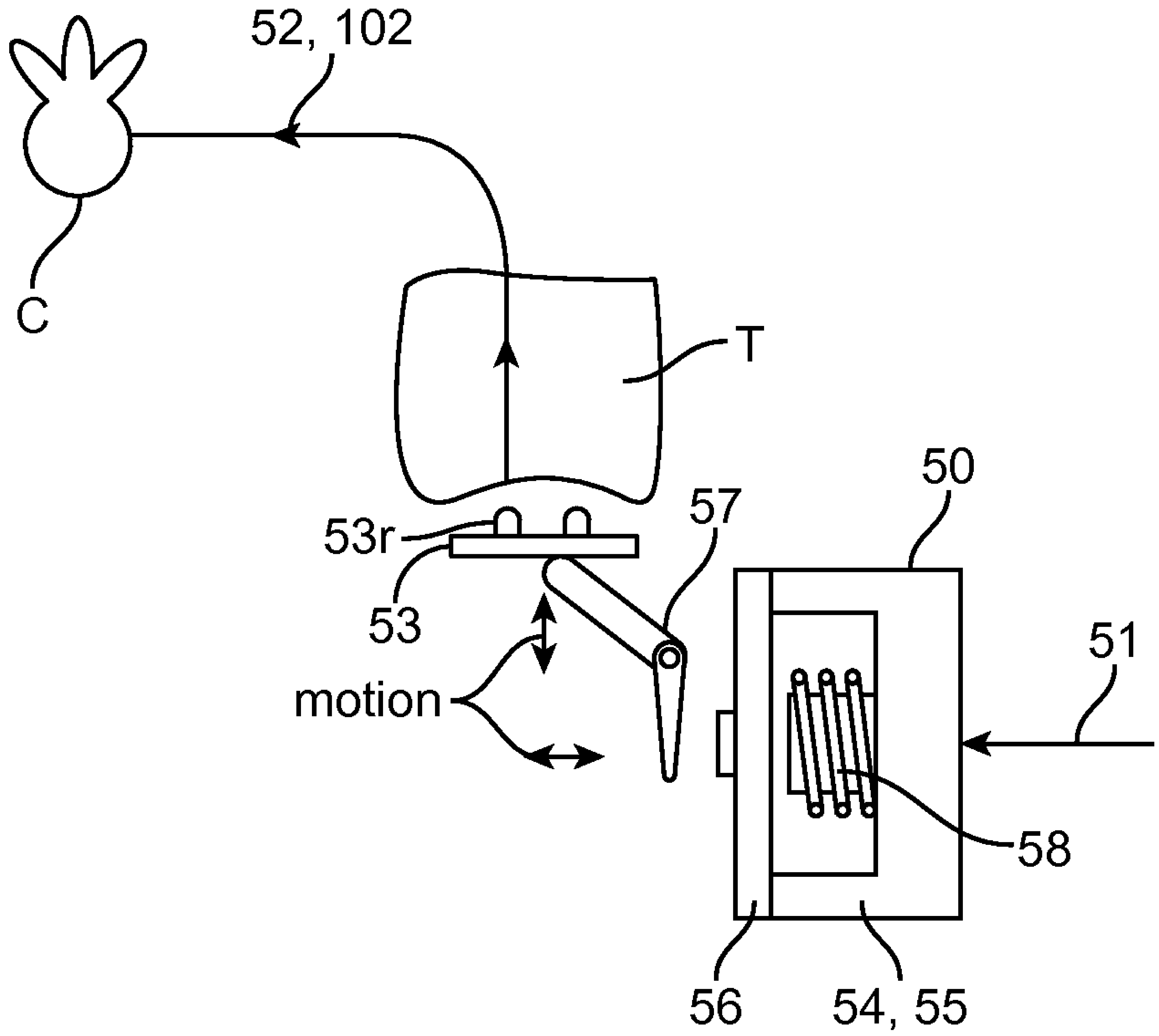


FIG. 6a

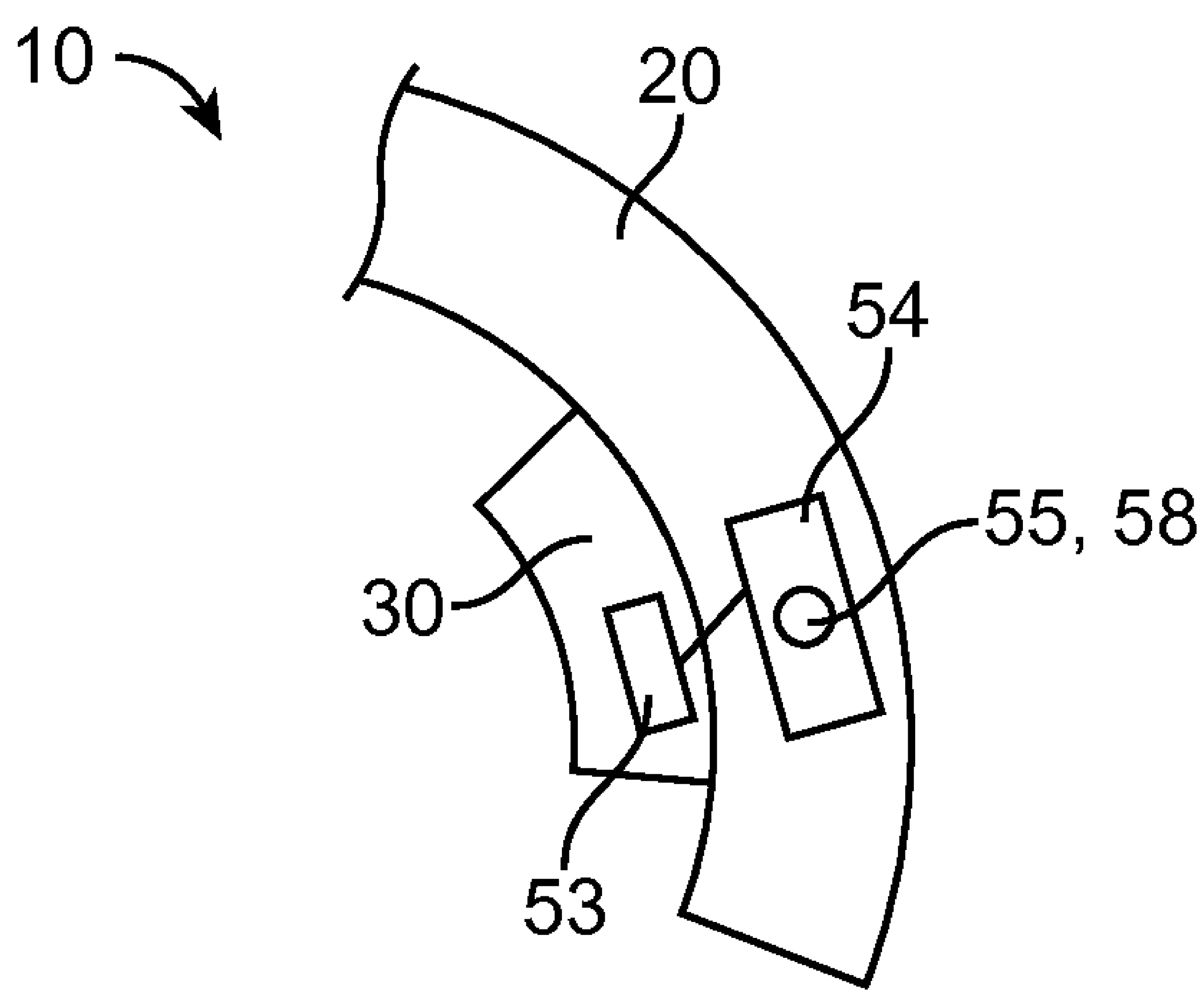


FIG. 6b

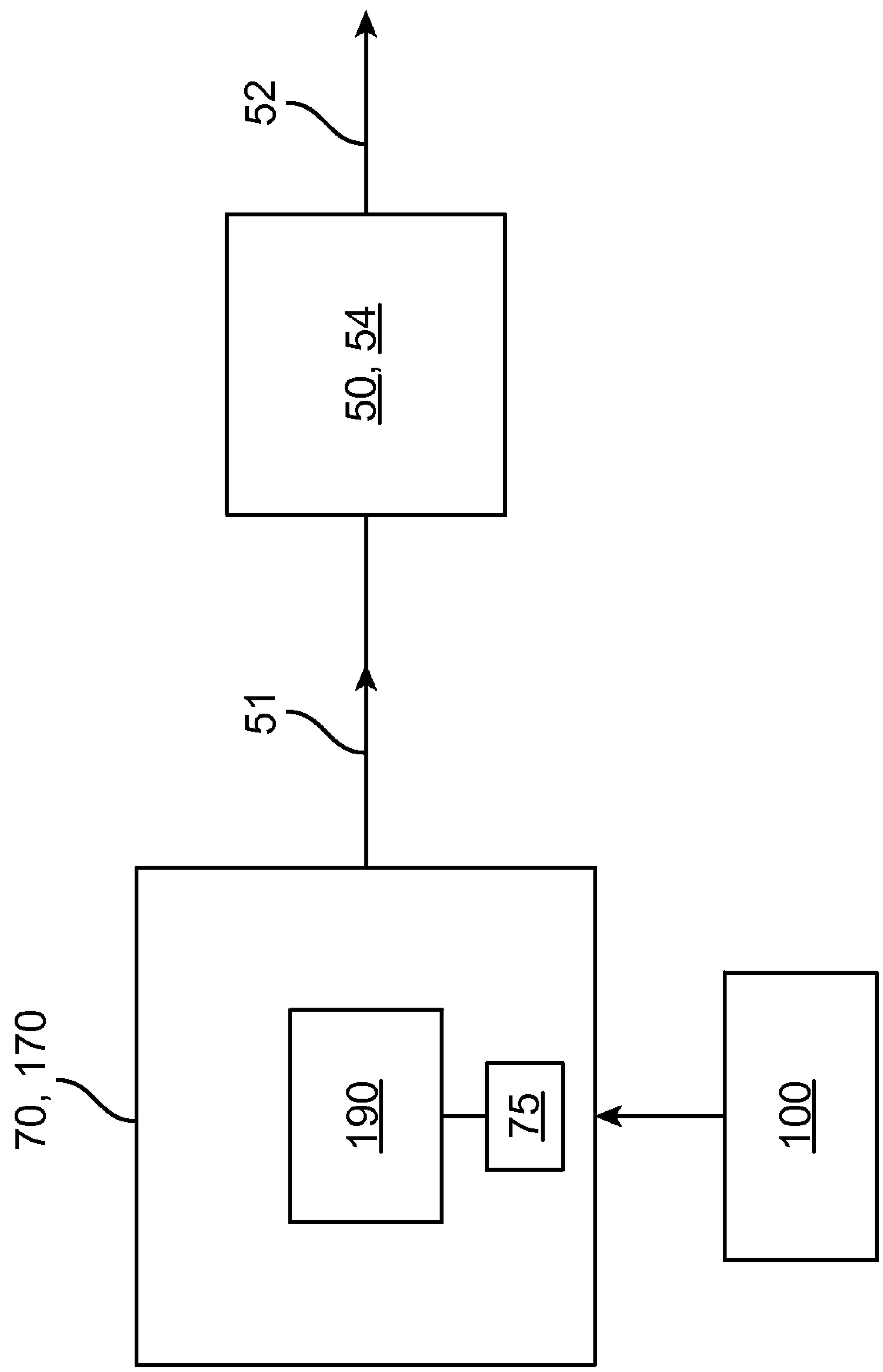


FIG. 6c

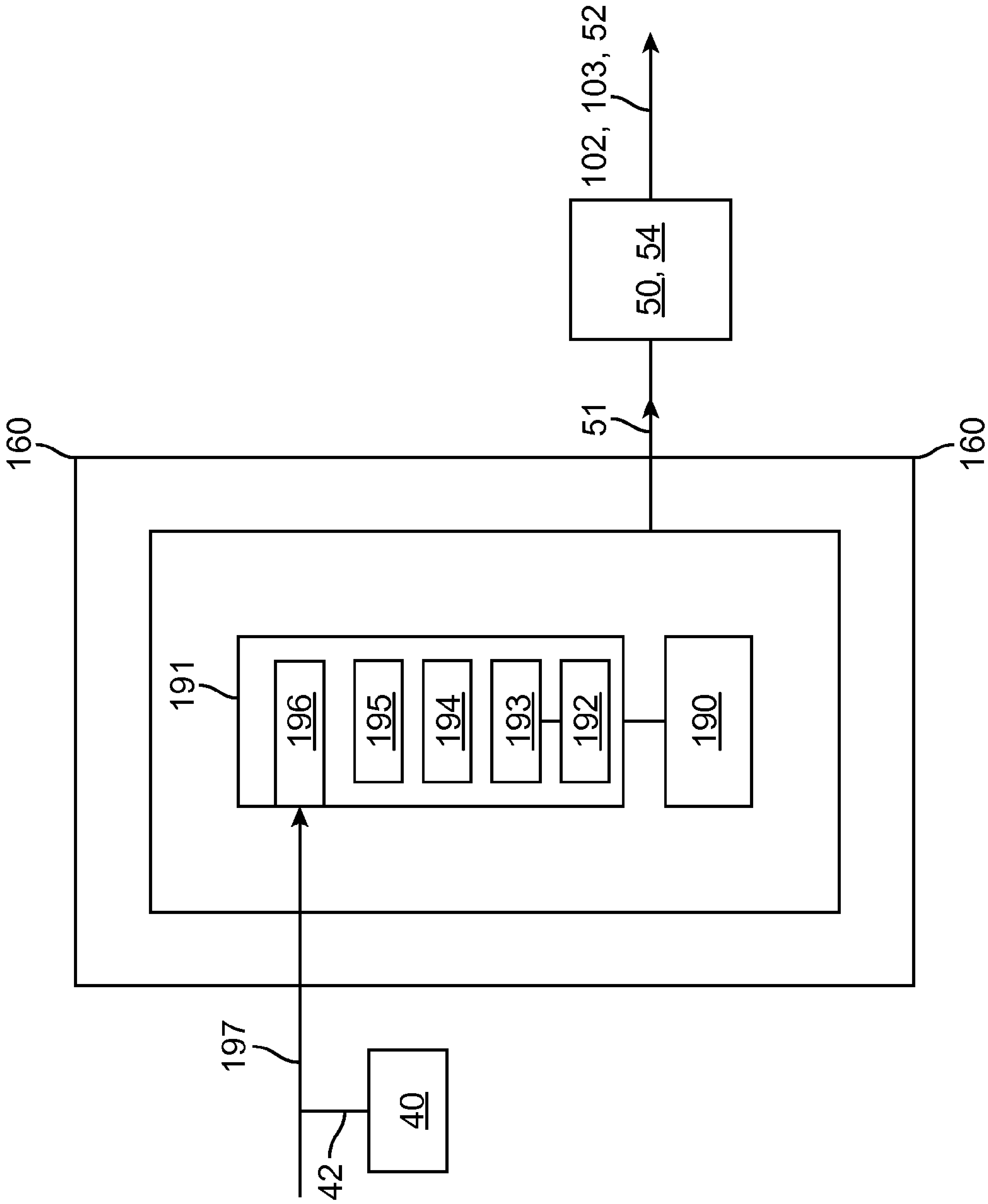


FIG. 6d

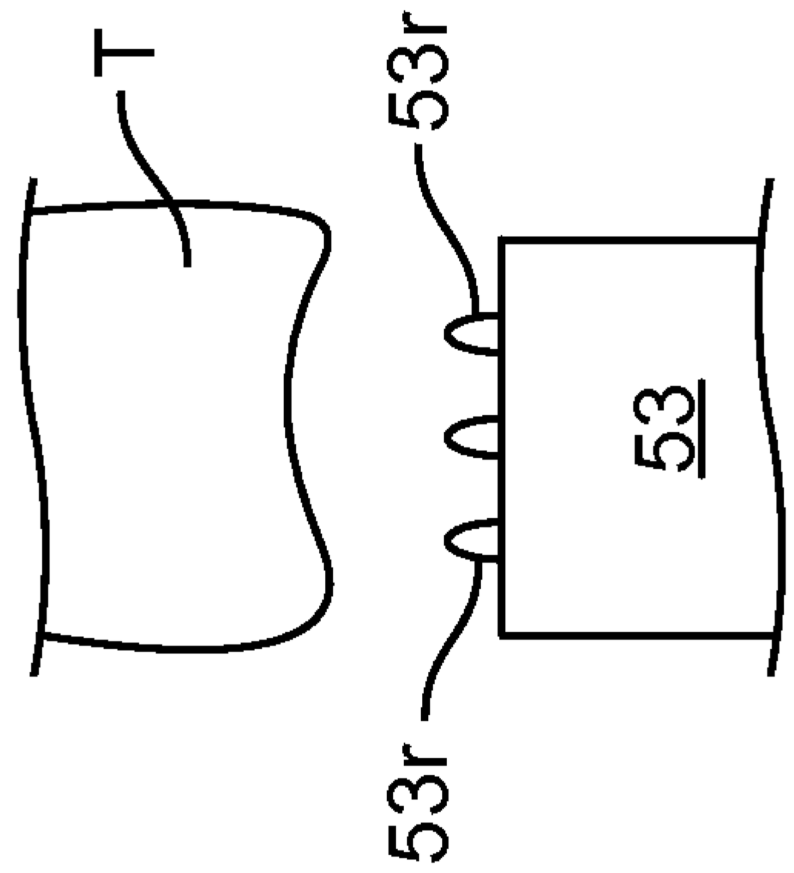


FIG. 7b

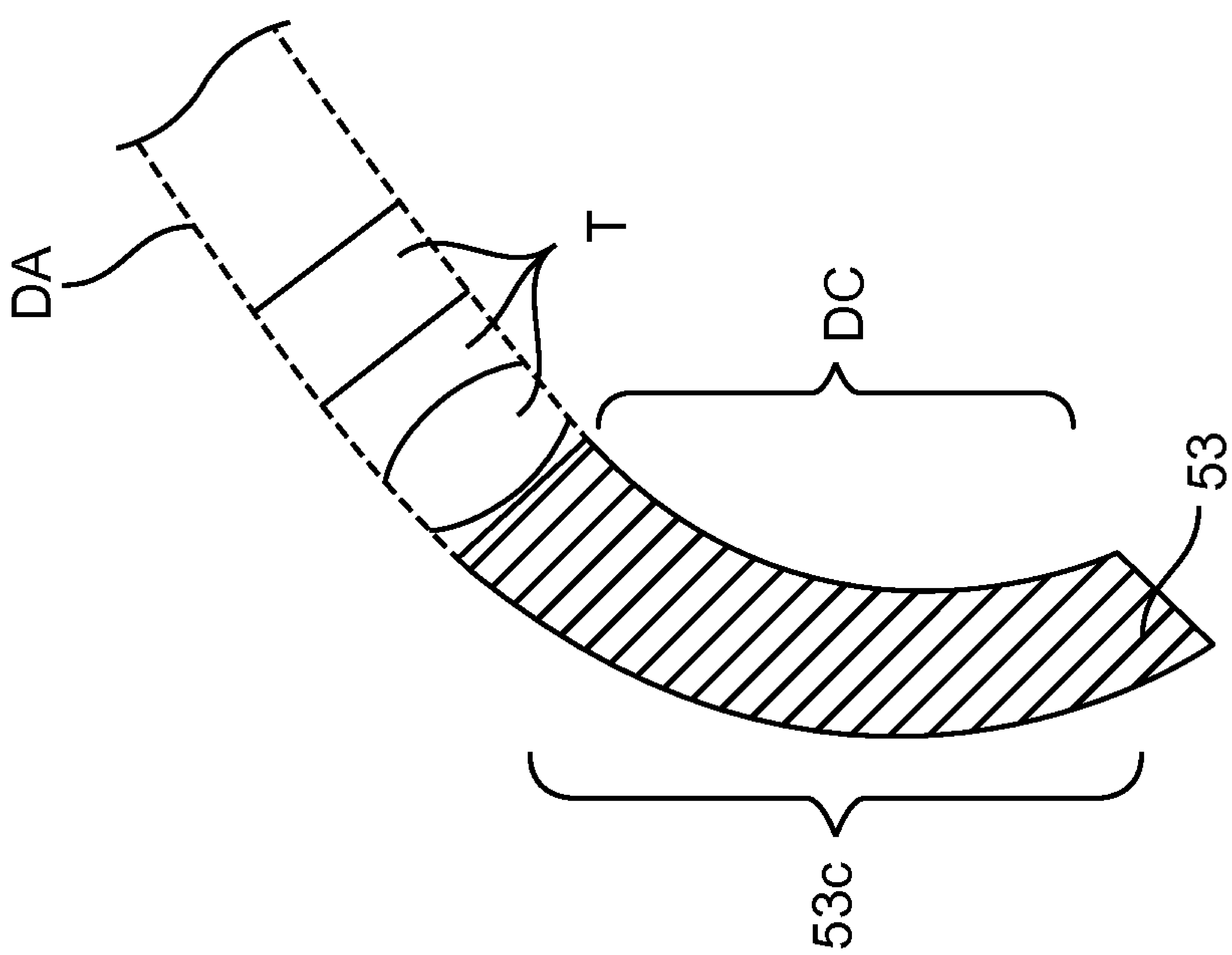


FIG. 7a

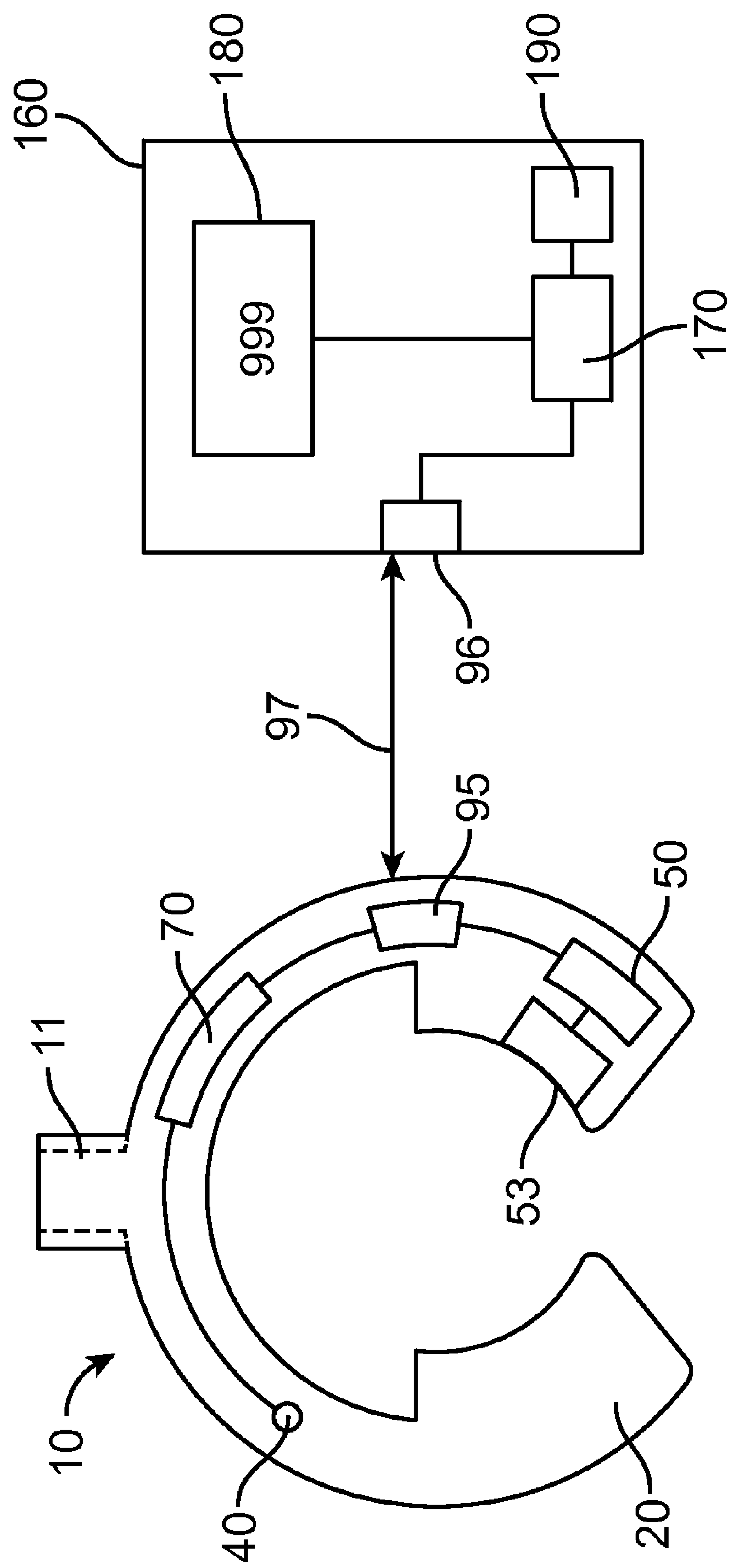


FIG. 8

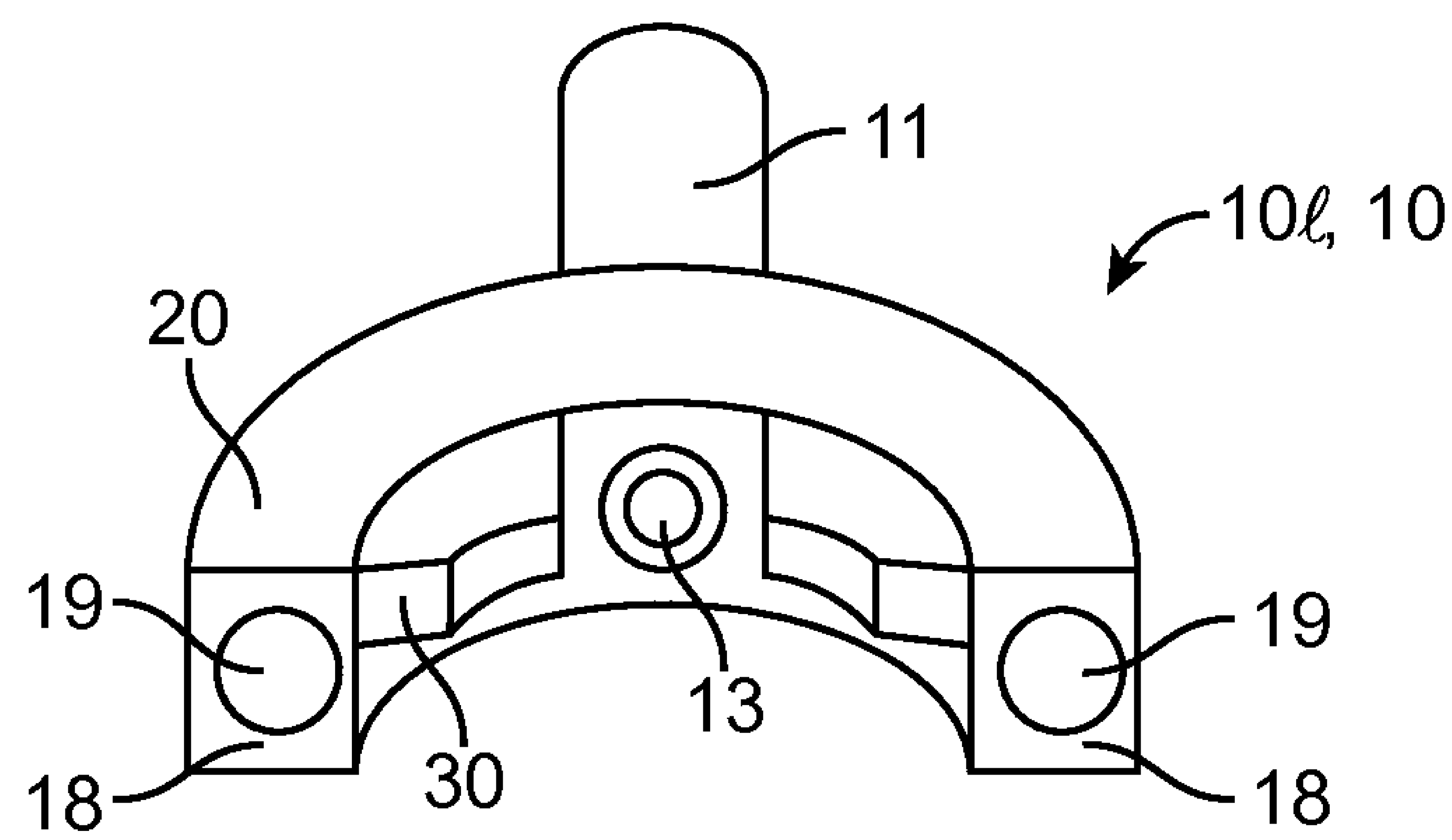


FIG. 9a

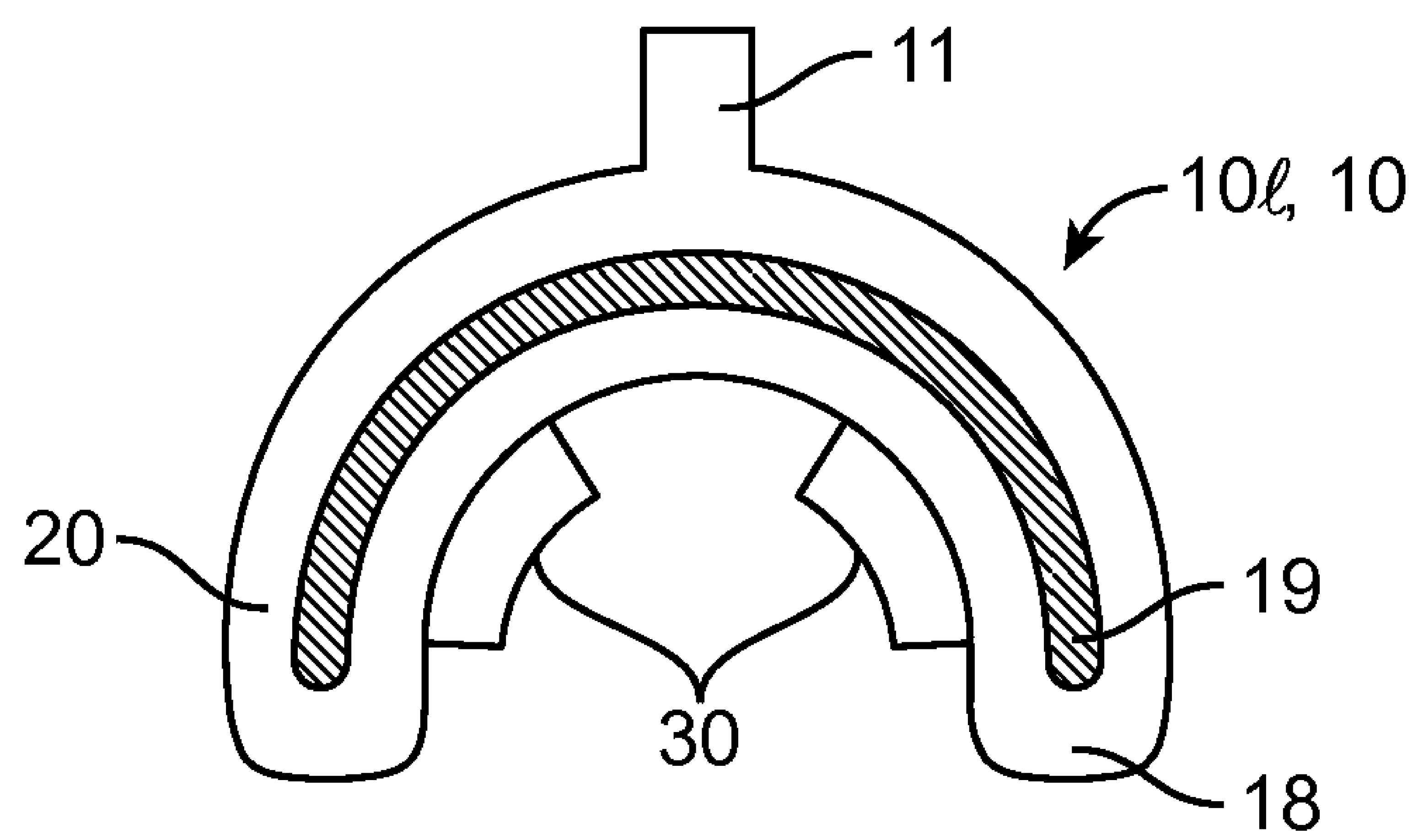
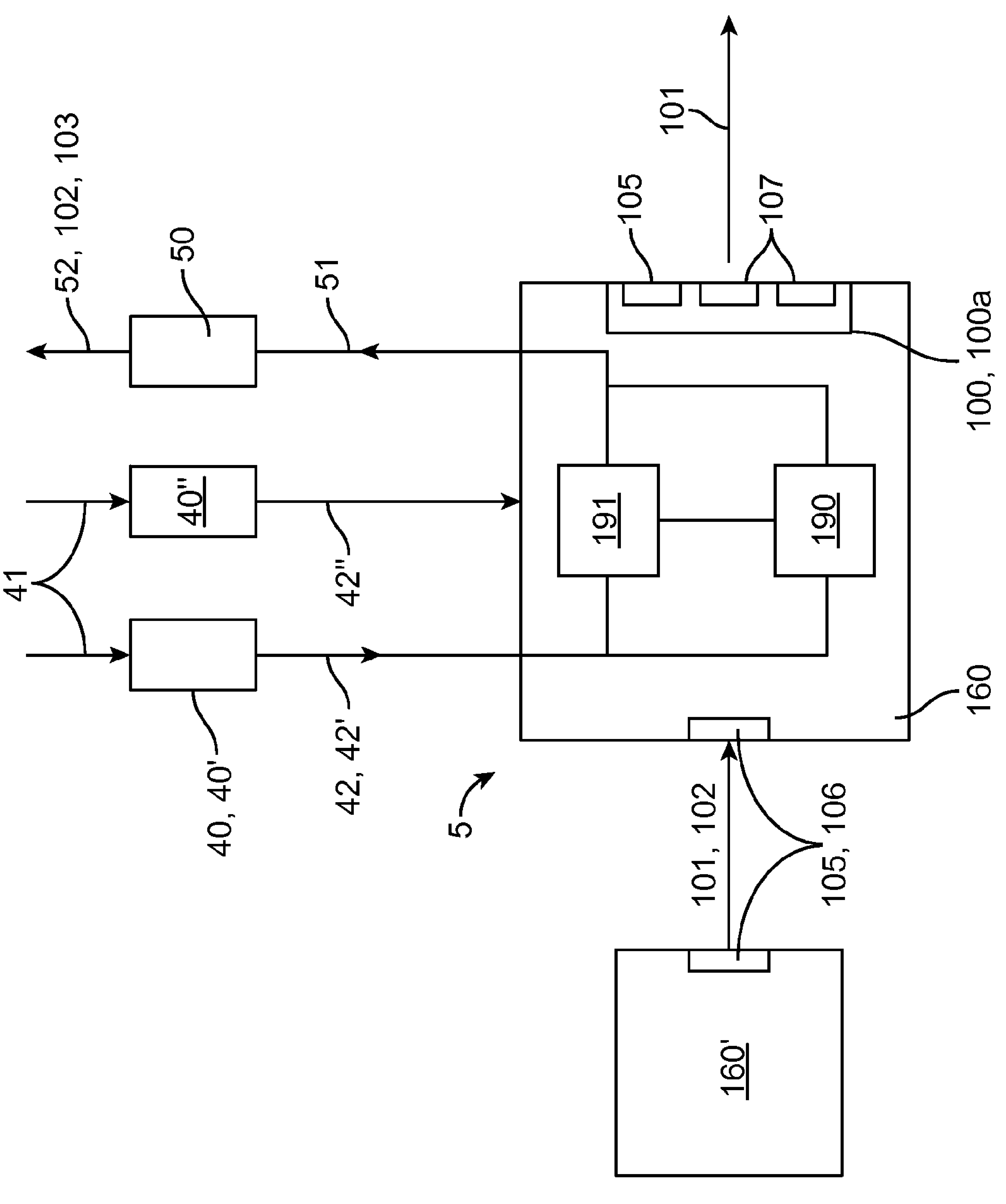


FIG. 9b


52, 102, 103
50
51
105
101
107
100, 100a
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40''
42''
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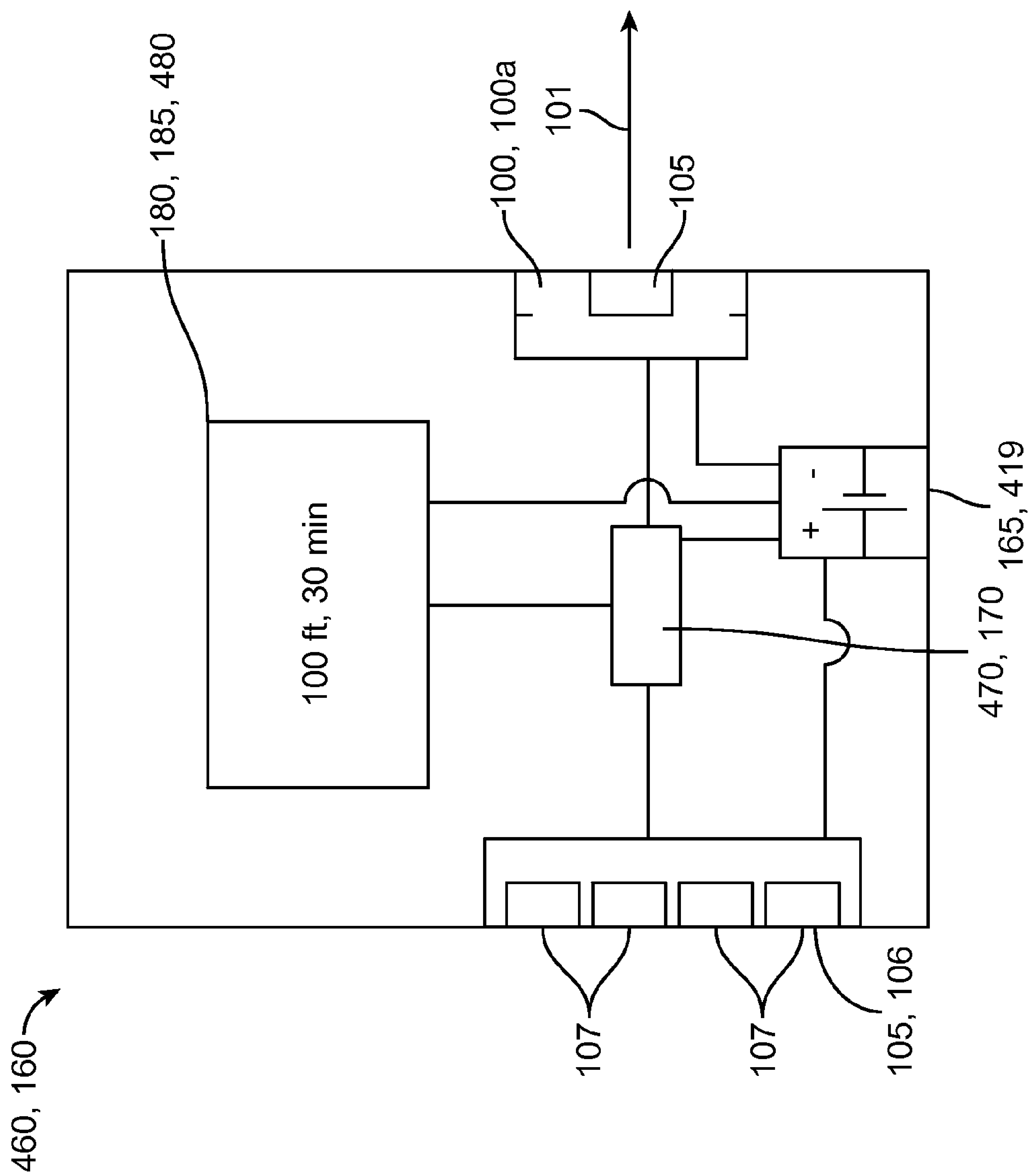
190
40, 40'
42, 42'
5
160
101, 102
105, 106
160'

FIG. 10


180, 185, 480
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101
105
100 ft, 30 min
165, 419
470, 170
107
107
105, 106
460, 160

FIG. 11

Fig. 12

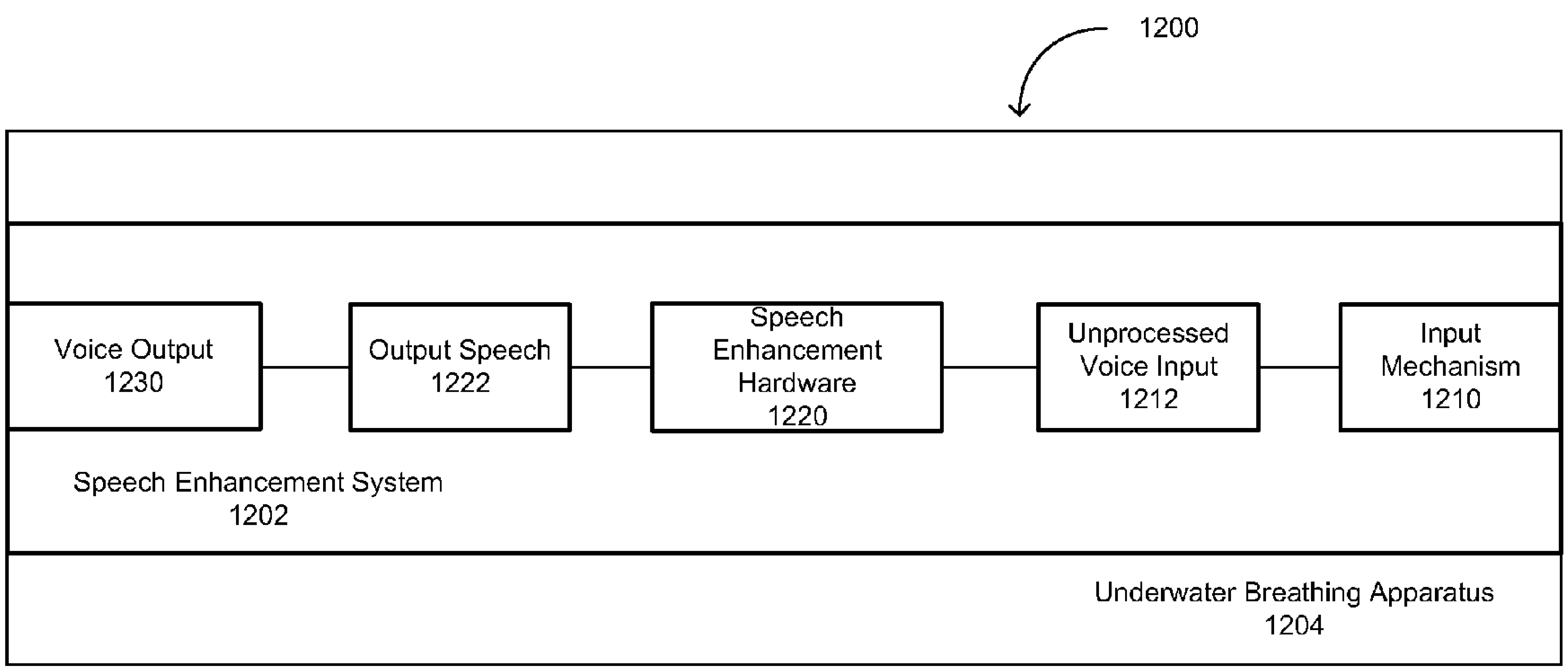
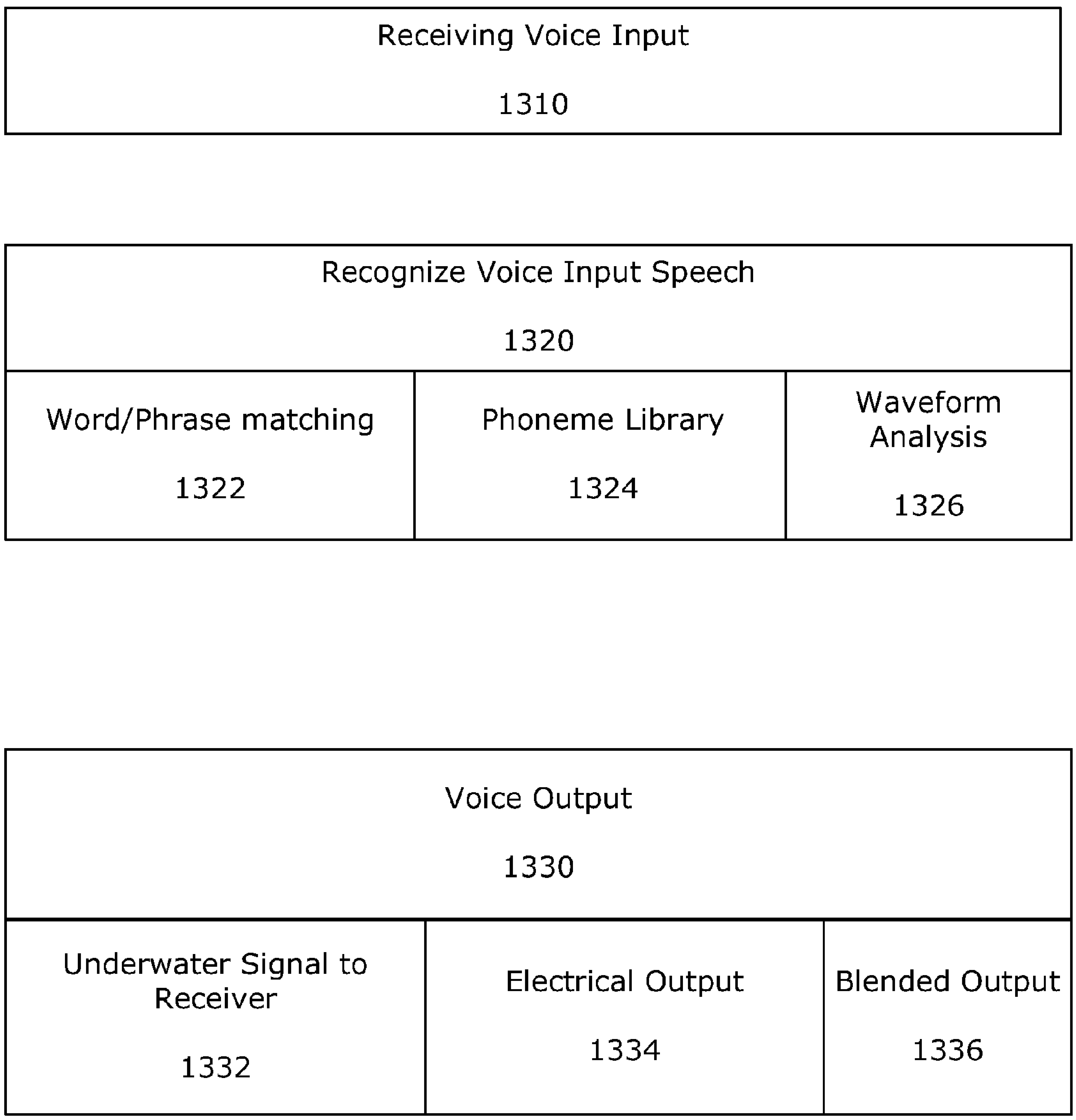

1200
Voice Output
1230
Output Speech
1222
Speech
Enhancement
Hardware
1220
Unprocessed
Voice Input
1212
Input
Mechanism
1210
Speech Enhancement System
1202
Underwater Breathing Apparatus
1204

Fig. 13

1300


Receiving Voice Input
1310
Recognize Voice Input Speech
1320
Word/Phrase matching
1322
Phoneme Library
1324
Waveform Analysis
1326
Voice Output
1330
Underwater Signal to Receiver
1332
Electrical Output
1334
Blended Output
1336

SYSTEM AND METHOD FOR ENHANCING SPEECH OF A DIVER WEARING A MOUTHPIECE

RELATED APPLICATIONS

This application claims priority to U.S. Provisional patent application Ser. No. 61/483,610 filed May 6, 2011; entitled SYSTEM AND METHOD FOR ENHANCING SPEECH OF A DIVER WEARING A MOUTHPIECE, which is fully incorporated by reference for all purposes.

This application is related to the following applications: U.S. patent application Ser. No. 13/398,718 filed, Feb. 16, 2012; entitled, Apparatus, System And Method For Underwater Signaling Of Audio Messages To A Diver"; U.S. patent application Ser. No. 13/231,881, filed Sep. 13, 2011; entitled, "Self-Propelled Buoy for Monitoring Underwater Objects"; U.S. patent application Ser. No. 13/237,912, filed Sep. 20, 2011; entitled, "Device, System and Method for Monitoring and Communicating Biometric Data of a Diver"; U.S. patent application Ser. No. 13/457,456, filed Apr. 26, 2012; entitled, "Mouthpiece for Measurement of Biometric Data of a Diver and Underwater Communication and U.S. patent application Ser. No. 13/352,249 filed Jan. 17, 2012; entitled, "Apparatus, System and Method for Underwater Voice Communication by a Diver," all of which are fully incorporated by reference for all purposes.

FIELD OF THE INVENTION

Embodiments described herein relate to a system for underwater voice communication. More specifically, embodiments described herein relate to a system and method for underwater communication by a diver, such as SCUBA or skin diver. Still more specifically, the present embodiments relate to a system for enhancing speech of a diver wearing a mouthpiece.

BACKGROUND

Since the early days of SCUBA (Self-Contained Underwater Breathing Apparatus) diving, communication between SCUBA divers has been an issue. This is due to the fact that the use of the SCUBA includes a mouthpiece worn by the divers which precludes direct voice communication. However, because of the risks involved in an underwater environment, divers have a critical need to communicate a variety of safety related messages to their fellow divers, e.g., communicating the amount of air they have remaining. As a result, a series of hand signs have been developed for underwater communication, but they only cover a very limited number of messages and cannot quickly get other divers' attention in critical situations. Various underwater graphical display devices have also been developed, but they have the same limitation as the hand signs. Furthermore, these devices which are worn on the diver's wrist or arm require the diver to divert his or her attention from what they are doing to look at the display. However, divers typically dive with their heads up to watch for their directions and with their arms besides their torsos to reduce the water resistance. Henceforth, the diver's natural diving position is not conducive to monitoring a visual alert on their wrist or elsewhere (e.g., arm or waist). This is even true for visual alerts being projected on the diver's face mask since the diver's attention is more focused on what is in front of them and not on what is projected on his or her face mask.

Acoustic alarm systems have also been developed, but they are code-based instead of voice-based. Therefore, such system can only communicate a limited number of messages and require the diver to understand their individual codes. Also, none of these devices provide for communication between divers and a surface craft such as a dive boat (a boat which transports and supports the divers). Further, none of these devices provides for communication between divers who are not in very close proximity. Thus, there is a need for an apparatus and an approach allowing for voice-based alerts to be communicated to the divers, for voice communication between divers while they are underwater, as well as for voice communication between divers and the surface craft.

BRIEF DESCRIPTION OF THE INVENTION

Embodiments described herein provide a system, apparatus and methods for underwater voice communication. One of the challenges of such a system is recognizing the speech of the diver when he or she is wearing a mouthpiece which limits the diver's the ability to pronounce various sounds. In some embodiments, an underwater communication system and/or device is provided to enable a diver (or other underwater person such as a snorkeler) to communicate more clearly with other divers or locations, such as surface boat locations.

Embodiments provide for the system including hardware and software for receiving and recognizing hindered speech ("hindered voice input") and then augmenting the speech with generated sounds ("voice output") corresponding to the intended speech sound or generating or replacing at least some of the diver's speech with synthesized words. The output may be in the speaker's own voice or a synthesized voice. In at least one embodiment, the hindered speech is made by a diver speaking with a mouthpiece in place. In an embodiment, the system comprises speech enhancement hardware to receive and recognize voice input, and to signal an output, in the context of an underwater breathing apparatus.

Embodiments include hardware, software or combinations thereof for processing obstructed spoken utterances of a diver who, under typical conditions, uses a mouthpiece and/or breathing apparatus that hinders and/or impedes normal speech. Embodiments process the speech to add clarity, or otherwise convert speech into an outputted form that is more intelligible (e.g. so as to simulate the diver's speech without obstruction from the mouthpiece).

In some embodiments, a device or apparatus is provided which includes memory resources (e.g. a buffer) for storing the diver's voice input. Further processing resources can be provided to recognize and substitute for obstructed or other unclear spoken utterances with speech output (synthesized or simulated) that corrects or otherwise clarifies the obstructed speech of the user.

In some embodiments, the voice output substitutes sounds where appropriate (e.g., by "blending" the substitutes with the originals) and plays back the blended speech as a whole so that the listener does not hear any breaks in the diver's spoken messages. For example, the module can include routines for removing or otherwise minimizing any pauses in the voice output so that the blended speech sounds continuous to the listener. In performing such an operation, the module can take a sampling of the diver's speech to determine the average interval between words and then use that to look for gaps which are larger than the average interval.

Still further, some embodiments allow a diver to speak and have two way voice communication with other divers and surface ships without having to remove their mouthpiece and without having any other specialized equipment. Such embodiments also allow the diver to communicate a full range of speech sounds to allow normal speech while the mouthpiece is in place. Embodiments of the invention also allow the diver to hear audio messages such as acoustic alarms, voice messages and prompts from a portable dive computer or other underwater electronic device. In use, such embodiments allow the diver to perform various tasks while receiving a variety of information including voice prompts and commands without having to look at a display, gauge or like device or apparatus. This enables the divers to stay focused on their task and/or their underwater environment, thus improving safety and their diving experience. Still other embodiments of the invention allow the diver to hear music, radio or other audio input while they are underwater. Still other embodiments can provide the diver with an acoustic input of sounds from the body of water in which he or she is diving allowing the diver to hear the sounds of underwater marine life as well as the sounds of surface craft.

An embodiment of a mouthpiece apparatus for underwater voice communication by a diver comprises a mouthpiece having an exterior coupling element for coupling to an air hose or other conduit of a SCUBA (or other underwater breathing apparatus) and an interior portion coupled to the coupling element and worn in the diver's mouth. The coupling element may be coupled directly to the air hose or to a fitting on the air hose. The coupling element and interior portion can include a lumen for the passage of respired air by the diver. The interior portion has a curved shaped corresponding to a shape of the diver's mouth and has attached right and left bite structures. The bite structures include upper and lower surfaces for engaging a bite surface of the user's upper and lower teeth. One or both of the bite structures may include a retaining flange which can be perpendicular to a bite surface of the bite structure for retaining the mouthpiece in the diver's mouth.

An acoustic transducer is positioned on the top surface of at least one of the left or right bite structures. The acoustic transducer is configured to transduce an electrical signal input (e.g., from another communication device or a dive computer) into an acoustic output and to acoustically couple to the diver's upper teeth in order to conduct the acoustic output from the diver's upper teeth through the diver's skull to generate audible sound in at least one of the diver's ears (e.g., to cochlea) when the diver is wearing the mouthpiece. Typically, the acoustic transducer is positioned to engage the upper (e.g., maxillary) back teeth of the diver's mouth, but may be positioned to engage any suitable tooth or group of teeth in the diver's mouth. Also, transducer properties can be tuned or otherwise adjusted. A microphone is positioned in or on the mouthpiece for detecting the diver's voice and generating an electrical output signal when the diver is wearing the mouthpiece. The microphone may be recessed or otherwise positioned to reduce breathing sounds. This microphone output can be sent to an underwater communication device for underwater transmission to another diver(s) or to a surface ship. In many embodiments, the communication device may correspond to an ultrasonic or other acoustical transmission device which transduces the electrical output signal into an acoustic signal, which is transmitted by the acoustical transmission device. Also, in various embodiments, one or both of the communication device or microphone may include a filter (e.g., high pass, low pass, etc.) for filtering out breath and related sounds of the diver from his or her spoken words.

In an exemplary embodiment of using the invention, the diver attaches an embodiment of the mouthpiece to a fitting on a regulator or other component of his or her SCUBA gear. For embodiments having electrical couplings on the mouthpiece, the diver may then connect them to the underwater communication device. He or she may perform a few quick tests to assure that the communication system is working. Such tests can include putting in the mouthpiece and saying some test phrases (e.g., "testing 1, 2, 3," etc.) while looking at a display on or coupled to the communication device to assure that a signal from the microphone is getting to the communication device. The test for the acoustic transducer can comprise putting in the mouthpiece and pressing a test signal button on the communication device which then sends a test signal to the acoustical transducer, which converts the electrical signal to an audio signal conducted through his teeth and skull, and which the diver then listens for. For either test, the diver can move the mouthpiece around in his or her mouth to find a position of the mouthpiece in their mouth which yields the best audio input and/or electrical output signal from the microphone. The diver may perform a similar procedure for embodiments of the mouthpiece used in a snorkel. Having found that position, the diver may select a particular acoustic frequency or range of frequencies (e.g., akin to a channel) to use for input (hearing) and output (verbal speech). The diver may choose to use the system underwater for voice communication with other divers as well as surface ship. Depending upon the frequencies available, the diver may then select/assign a distinct acoustic frequency or frequency range for a particular diver as well as for a surface craft. In many embodiments, the system will allow for separate frequency and/or frequency range to minimize cross talk from diver to diver as well as diver to surface ship communication. These and other aspects, embodiments and features are described in detail in the body of specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of an embodiment of an underwater voice communication system for a diver.

FIG. **1***a* shows an embodiment of a voice communication mouthpiece apparatus worn in the mouth and its use in the conduction of sound to the inner ear through the skull.

FIG. **2** is a lateral view illustrating embodiments of the mouthpiece coupled to an underwater breathing apparatus such as a SCUBA.

FIG. **3** is a perspective view showing various features of an embodiment of the mouthpiece.

FIG. **4** is a lateral view showing an embodiment of the mouthpiece having an electrical connection means such as a wire for coupling to portable watertight electronic (PWE) devices such as a dive computer.

FIG. **5***a* is a side cut-away view showing an embodiment of the mouthpiece having a cavity and a microphone positioned in the cavity.

FIG. **5***b* is a block diagram illustrating the configuration and operation of an embodiment of the microphone.

FIG. **6***a* is a side cut-away view showing an embodiment of the acoustic transducer comprising an electromagnetic driver, acoustical plate and a connecting lever.

FIG. **6***b* is a top down view showing an embodiment of the acoustic transducer positioned in/on the mouthpiece.

FIG. **6***c* is a block diagram showing the configuration and operation of an embodiment of the acoustical transducer.

FIG. **6***d* is a block diagram showing the configuration and operation of an embodiment of a communication system for generating voice prompts and other messages that are delivered to the diver by embodiments of the acoustical transducer.

FIG. **7***a* is a top down view illustrating an embodiment of the acoustic plate having a curved shape corresponding to curvature of the diver's dental arches.

FIG. 7*b* is a side view illustrating an embodiment of the acoustical plate having conducting ridges.

FIG. **8** illustrates an embodiment of the mouthpiece having a wireless communication device such an RF communication chip for communicating with a diver computer or other PWE device.

FIG. **9***a* is a cut away perspective view illustrating an embodiment of a multilayer mouthpiece having a rigid core and softer outer layer.

FIG. **9***b* is a cut away top down view illustrating an embodiment of a multilayer mouthpiece having a rigid core and softer outer layer.

FIG. **10** is a schematic view illustrating the configuration and operation of an embodiment of the communication device for use with embodiments of the voice communication mouthpiece apparatus.

FIG. **11** is a schematic view illustrating the configuration and operation of an embodiment of a PWE device including a communication device for use with embodiments of the voice communication mouthpiece apparatus.

FIG. **12** is a simplified block diagram illustrating an embodiment of the system including speech enhancement hardware in an underwater breathing apparatus to receive and recognize voice input and to produce a voice output.

FIG. **13** is a simplified block diagram illustrating an embodiment including exemplary modules for recognizing voice input speech and producing voice output.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. **1-11**, an embodiment of a communication system **5** for voice communication from a first diver **200** to one or more other divers **210** or surface ships **220** comprises a voice communication mouthpiece apparatus **10** (herein mouthpiece **10**) and an underwater communication device **100**. In various embodiments, communication system also provides for communication of computer generated voice messages to the diver from a portable underwater device. Mouthpiece **10** is worn in the diver's mouth and is configured to attach to a regulator **82** or other fitting **83** of a self-contained underwater breathing apparatus (SCUBA) **80** or other underwater diving apparatus. System **5**, including mouthpiece **10**, is configured to allow voice or other communication between a first underwater communication device **100** carried by diver **200** and a second underwater communication device **110** carried by other diver(s) **210** as well as between communication device **100** and a communication device **130** used by a ship **220**. In one embodiment, communication device **130** can be incorporated into a buoy or array towed by ship **220**. With regard to communication device **100** (and **110**), it can be positioned on a variety of locations on the diver and/or on SCUBA **80**. In one embodiment, it may be positioned on the diver's head and can be attached using a band or strap or it may be coupled to the hood of the diver's wetsuit. In many embodiments, communication device **100** may be incorporated into a portable watertight electronic (PWE) device **160** carried or worn by the diver as is described herein.

In addition to communication with another diver **210** having a separate SCUBA **80**, in various embodiments, system **5** and mouthpiece **10** can also be adapted for communication with another mouthpiece **10'** connected to a buddy breathing line **16** connected to same SCUBA **80** as used by diver **200** as is shown in the embodiment of FIG. **1**. In such embodiments, mouthpieces **10** and **10'** can be configured to both be operatively connected to the same communication device **100** or they may be configured to be directly connected to each other without the use of communication device **100**. In use, such embodiments allow quick and ready communication between the diver **200** and a buddy breather without the need for any communication device or any set up procedure.

The mouthpiece **10** includes a coupling element **11**, an interior portion **20** coupled to the coupling element **11**, a microphone **40** and an acoustic transducer **50**. Coupling element **11**, couples the mouthpiece **10** to SCUBA **80**. In various embodiments, coupling element **11** may be configured to couple directly to an air hose **81** of SCUBA **80** or a regulator **82** or other fitting **83** of SCUBA **80**. The coupling element **11** and the interior portion **20** include a lumen **13** for the passage of respired air by the diver.

One or both of the microphone **40** and the acoustic transducer **50** may be powered by a battery **90** which is incorporated into the mouthpiece **10** or coupled to the mouthpiece **10**, for example, by an electrical wire **17** or other electrical connection means. Battery **90** may comprise various lithium buttons or other suitable batteries such as miniature batteries known in the art. Battery **90** may also be shaped to have a form factor which readily fits into mouthpiece **10**. For example, in one embodiment, battery **90** may have curved shape which corresponds to the curvature of the diver's dental arches DA. Battery **90** may also be used to power a processor **70** that may also be contained in the mouthpiece **10**.

Wire(s) **17** may also be configured to couple both the microphone **40** and the transducer **50** (as well as other suitable electrical components of mouthpiece **10**) to various electrical devices that are part of SCUBA **80** or are otherwise worn or carried by the diver, such as communication device **100** and/or a dive computer **160**. Wire(s) **17** may be insulated sufficiently to withstand depths of several hundred feet or more. A portion of the wires **17** may be embedded in the mouthpiece **10** and/or connected to the mouthpiece **10** by an electrical connector configured for underwater conditions. Wire **17** can include at least a first and second wire for connection to the microphone **40** and the acoustic transducer **50**. In some embodiments, a section of wire **17** may pass through lumen **13** of coupling element **11** so as to connect to one or more electrical devices that are part of SCUBA **80** or are otherwise worn or carried by the diver. In such embodiments, wire **17** is sufficiently thin or otherwise configured so as to not interfere or impede the passage of respired air through lumen **13**.

In alternative or additional embodiments, one or both of the microphone **40** and the transducer **50** may be operatively coupled to communication device **100** and/or dive computer **160** via use of a wireless communication device, such as a radio frequency (RF) communication chip **95**. RF communication chip **95** may correspond to an active or passive RF transceiver and may be embedded in the mouthpiece **10**. The frequency and power levels for use with such an RF communication chip **95** can be adapted for underwater use to allow communication of signals **97** between the RF communication chip **95** in the mouthpiece **10** and a corresponding chip **96** in communication device **100** and/or dive computer **160** carried by the diver. In use, such embodiments, allow the diver to couple the mouthpiece **10** to communication device **100** and/or computer **160** without having to make any physical connections. They also allow the diver to verify that the mouthpiece **10** is operating properly before getting into the water through the use of one or more diagnostic software modules **190** resident within dive computer **160**. The software modules **190** can be configured to interrogate mouthpiece **10** for proper operations. In one embodiment, this may consist of the diver being prompted to speak several test phrases with the mouthpiece in place. Further, in various embodiments, communication chip **95** may include memory resources **75** coupled to chip **95** and may contain various diver specific information (e.g., name, weight, health data, dive history etc.), which can be signaled to dive computer **160** allowing the dive computer to uniquely identify the mouthpiece **10** as belonging to a particular diver and then upload that data into the dive computer **160**. The process may also be facilitated by use of a processor **70**, such as microprocessor **70**, which controls the handshake and other communication between communication chip **95** and chip **96**. Processor **70** may also be coupled to memory resources **75**. In particular embodiments, such a configuration can be implemented through use of an ASIC (application specific integrated circuit) containing processor **70**, and memory resources **75**

The interior portion **20** of the mouthpiece **10** has a curved shape **21** corresponding to a shape of the diver's dental arches DA and has attached a right bite portion **31** and a left bite portion **32**. Together, the right bite portion **31** and the left bite portion **32** form bite structures **30**. The curved shape **21** may be fabricated by taking a dental impression or image of the diver's mouth and then using that impression or image to construct a mold for making the mouthpiece and/or using stereolithography techniques known in the art. The bite structures **30** include an upper surface **33** and a lower surface **34**, which together form bite surfaces **35**. The bite surfaces **35** are for engaging a bite surface BS of the diver's teeth T, including the diver's upper teeth UT (also called maxillary) and lower teeth LT. Bite structures **30** may be positioned and arranged to contact at least the back teeth of the diver, but may contact the front teeth or other teeth as well. The bite structures **30** may also be acoustically isolated from each other by fabricating all or a portion of the bite structures from various acoustically insulating materials known in the art.

In various embodiments, one or both of the bite structures **30** may include a retaining flange **36** for retaining the mouthpiece in the diver's mouth M by contacting an inside surface of the diver's teeth. Typically, flange **36** will be oriented perpendicular to bite surfaces **35**, but other orientations are also contemplated (e.g., an acute angle). Also, flange **36** may have a curved shape or profile **37** which corresponds to the curvature of the diver's dental arches DA.

In various embodiments, mouthpiece **10** may be fabricated from elastomeric polymers such as silicone, polyurethane, copolymers thereof and other elastomers known in the art. The mouthpiece **10** may have a unitary construction and or may be fabricated from separate components which are joined. It may be fabricated using various methods known in the polymer processing arts, including molding and stereolithography methods. Also, molding may be done with the microphone **40** and/or acoustical transducer **50** in place, or they may be added to cavities created in the mouthpiece **10** for their positioning. The polymeric materials for the mouthpiece **10** may be selected for several different mechanical and acoustical properties. For example the material can be selected to achieve a desired durometer for the mouthpiece **10**. The durometer of the material may be selected to maintain the shape of the mouthpiece **10**, but at the same time, reduce the bite force required for the diver to hold the mouthpiece **10** in place. Suitable lower durometer embodiments, include the range of 20 to 50, more preferably, 30 to 40. In use, such lower durometer embodiments allow the diver to keep the mouthpiece **10** in their mouth for extended periods (e.g., hours) without excessive discomfort or fatigue of their jaw muscles, particularly while speaking. The properties of the polymers used for the mouthpiece **10** can also be selected to obtain a desired amount of acoustical insulation so as to minimize the transmission of sound from transducer **50** to microphone **40** so as to reduce or prevent feedback between the two.

In some embodiments, the mouthpiece **10** having a lower durometer can be achieved by two ply and/or other multilayer configurations of the mouthpiece **10** where at least a portion of the mouthpiece **10** comprises a lower durometer tooth contacting surface layer **18** (also referred to as a liner) which fits over a higher durometer (e.g., more rigid), underlying core structure **19**. The latter provides sufficient rigidity for holding the shape of the mouthpiece **10** in the diver's mouth, while the former provides a soft comfortable tooth contacting surface. Liner **18** may also be configured to provide acoustical insulation/dampening properties so as to reduce feedback between microphone **40** and transducer **50** by reducing the transmission of sound from transducer **50** and microphone **40**. In use, such two ply or other multilayer embodiments of the mouthpiece **10** provide a more comfortable mouthpiece and one that minimizes or reduces feedback from the transducer **50** and microphone **40**, while maintaining the shape of the mouthpiece. In related embodiments, mouthpiece **10** can have a three or even a four ply construction to provide additional amounts of acoustic insulation.

Microphone **40** is positioned in or on mouthpiece **10** and is configured to detect the sound **41** (herein voice sounds **41**) from the diver's voice with the mouthpiece **10** in place and generate an electrical output **42**. Microphone **40** may comprise various miniature microphones known in the art and may comprise various electric microphones known in the art. The microphone **40** may include or be coupled to a preamplifier **47** as well as a filter device **43** for filtering out the diver's breath sounds or other non-speech related sounds (e.g., bubble and cavitation sounds). In various embodiments, filter **43** may correspond to one or more of a high pass, low pass or band pass filter. Filter **43** may also be programmable to allow the user to select various acoustic criteria for filtering out breathing sounds. Such criteria may include a particular frequency range, duration of sound and/or amplitude of sound that is filtered. Filter **43** may also be configured to filter out acoustic signals **52** (discussed below) generated by acoustical transducer **50** so as to minimize feedback from transducer **50** and microphone **40**. In an alternative or additional embodiment, filter **43** may also be configured as or include a switching device **43*s*** that shuts off the generation of signals **42** by microphone **40** when the diver is receiving signal acoustic signals **52** from transducer **50**. In use, such embodiments provide another approach and means for minimizing or eliminating feedback between microphone **40** and acoustic transducer **50**.

Microphone **40** may be placed in any number of locations in or on the mouthpiece **10**. According to the present embodiments, microphone **40** is placed on an opposite side **22** of the mouthpiece to the side that contains acoustic transducer **50** so as to minimize feedback between the microphone and acoustic transducer **50** (side **22** being defined by the diver's left and right). In particular embodiments, the microphone is placed on the opposite bite structure **30** from that of acoustic transducer **50**. In such embodiments, bite structure **30** is configured to dampen or attenuate any vibrations coming from acoustical transducer **50**. Also, microphone **40** may also be placed on the surface **12** of mouthpiece **10**, but is more preferably recessed within the mouthpiece so as to attenuate breath sounds as well as reduce the likelihood of exposure to liquids in the diver's mouth.

In the embodiments of the mouthpiece **10** having a recessed microphone **40**, the mouthpiece **10** can include a cavity **44** in which the microphone **40** is placed. The cavity **44** may include a small aperture **45** or opening to the mouthpiece surface **12** to allow for acoustical conduction to the mouthpiece **10**. The diameter of aperture **45** can be selected to minimize the entry of fluids into the cavity, and in various embodiments, can be in the range of 0.001 to 0.00001 inches (0.00254 to 2.54e-005 centimeter), and more preferably, 0.0005 to 0.0008 inches (0.00127 to 0.002032 centimeter). In a specific embodiment, the diameter of aperture **45** is 0.0007 inches (0.001778 centimeter). One or both of aperture **45** and microphone **40** may include a waterproof layer **46**, which may correspond to a porous material such as an expanded polytetrafluoroethylene (PTFE) material. Also, in the embodiments of the mouthpiece **10** having the cavity **44**, the microphone **40** may also be potted in cavity **44** with a sound insulating material, such as one or more curable polymers having sound insulating properties (e.g., silicone). In use, such embodiments having the potted microphone **40** provide a means for reducing feedback between microphone **40** and acoustic transducer **50** as well as for dampening of other unwanted sounds (e.g., from the diver clenching his jaw on the mouthpiece), which may be conducted through mouthpiece **10**.

Acoustic transducer **50** is positioned on the upper surface **33** of at least one of the left and/or right bite structures **30**. The acoustic transducer **50** is configured to transduce an electrical signal input **51** (encoded or corresponding to an acoustic signal) received by the diver's communication device **100** into an acoustic output signal **52**. Input signal **51** can be from one or more of another communication device **100** (e.g., carried on either another diver or a surface ship), a dive computer, a music player (e.g., an MP3 player) or other related devices. In particular embodiments, input signal **51** can be generated and/or conditioned by a processor **170** (described herein below) or other signal conditioning device or circuitry of communication device **100** or a processor **70** resident within mouthpiece **10**. Processor **70** or **170** may correspond to a microprocessor and can be configured to generate, and/or condition signal **51**, as well as condition signal **42** from microphone **40**. Such signal conditioning in either case can include one or more of amplification, filtering, conversion, matching and isolation.

Transducer **50** is also configured to acoustically couple to the diver's upper teeth UT to conduct the acoustic output **52** from the diver's upper teeth through the diver's skull S to the diver's cochlea in order to generate audible sound in at least one of the diver's ears E when the diver is wearing mouthpiece **10**. In many embodiments, the transducer **50** comprises an acoustical plate **53** (or a vibrating plate) coupled to a driver **54**. The plate **53** is configured to engage with and is acoustically coupled to the surface of the diver's teeth. The plate **53** is to be vibrated by the driver **54** responsive to electrical signal **51**. Vibration of the plate **53** produces acoustical signal output **52** which is acoustically conducted to the diver's teeth and then through the bones in his or her skull S to the inner ear IE including cochlea C where they are perceived as sound. Plate **53** can be fabricated from ceramic, metal, polymeric material such as a resilient polymer, and can have a size and shape to acoustically couple to one or more of the diver's teeth. In particular embodiments, plate **53** may have a curved horizontal shape **53***c* corresponding at least in part to the curvature of the diver's dental arches DA to facilitate the plate contacting multiple teeth. Plate **53** may also have one or more ridges or other raised feature **53***r* configured to enhance acoustical coupling and conduction to the diver's teeth. In particular embodiments, ridges **53***r* can be positioned to contact the center depressions in the diver's teeth.

In particular embodiments, plate **53** can be configured to have an acoustical impedance approximating or otherwise matched in a certain fashion (e.g., proportional, inversely proportional, etc.) to that of the diver's teeth (e.g., one or more of the upper teeth). Such embodiments can be achieved by fabricating plate **53** from one or more dental ceramics or other material having similar mechanical properties as the diver's teeth. Other acoustic properties can also be so matched such as the resonant frequency of the plate and the teeth. Such matching of acoustic properties can be configured to minimize acoustic losses from plate **53** to the teeth or otherwise enhance conduction of acoustic signal **52** through the diver's skull S to the inner ear IE including the cochlea C.

In various embodiments, driver **54** comprises an electromagnetic driver **55**, which can be directly or indirectly coupled to plate **53**. In the embodiments that driver **55** is indirectly coupled to plate **53**, driver **54** comprises the electromagnetic driver **55**, a movable diaphragm **56** sitting atop or otherwise coupled to the driver **55**, and a lever **57** or other connecting means coupling diaphragm **56** to plate **53**. Electromagnetic driver **55** can comprise various electromagnetic drivers known in the speaker or earphone arts and can comprise a miniature magnet **58** which may correspond to a core or coil. One or more of driver **55**, movable diaphragm **56**, lever **57** and magnet **58** can be fabricated from microelectromechanical-systems-based (MEMS-based) components either separately or as a single structure. In alternative embodiments, driver **55** may be configured to be directly coupled to plate **53** without diaphragm **56** and/or lever **57**.

Typically, acoustic transducer **50**, including plate **53**, is positioned to engage the upper (e.g., maxillary) back teeth of the diver's mouth M, but may be positioned to engage any suitable tooth or group of teeth in the diver's mouth such as the front either upper or lower teeth. As an addition or alternative embodiment, transducer **50** including plate **53** may also be configured to engage with and be acoustically coupled to the diver's upper palate (the hard palate). In such embodiments, the plate **53** can have a curved shape matched to at least a portion shape of the upper palate (also known as the roof of the mouth). Such embodiments allow for larger surface area of acoustical conduction to the diver's skull and do not require the diver to bite down on the mouthpiece when speaking.

In various embodiments, mouthpiece **10** can include a sensor **60** which is configured to detect the diver's breath and generate an output signal **61**, which is used to switch off microphone **40** and/or to attenuate or gate the output signal **42** coming from the microphone to communication device **100** during a time period of the diver's respiration (e.g., like a squelch function). In the first configuration (where the microphone is switched off), the output signal **61** can be fed into microphone switching device **43***s*, and in the second signal **61** can be sent to communication device **100** including processor **170**. In many embodiments, sensor **60** can correspond to a miniature flow/velocity sensor for detecting a flow rate and/or velocity of the diver's breath moving through the mouth. When the velocity or flow rate exceeds a threshold value, corresponding to flow rate or velocity of the diver's breath, the microphone **40** can be configured to shut off, and/or output signal **42** can be attenuated or gated by processor **170**. The threshold value for flow rate and/or velocity can be selected so as to be able to distinguish between a velocity or flow rate when the diver is speaking or breathing, the former being lower than the latter. In various embodiments, processor **170** and/or microphone **40** may include logic for shutting off the microphone **40** and/or attenuating or gating signal **42** or **51**. In specific embodiments, such logic for attenuating or gating signal **42** or **51** can be incorporated into one or more modules **190**

For embodiments where sensor **60** comprises a flow sensor, the sensor can be positioned in a variety of locations on mouthpiece **10** for detecting the divers' breath. In preferred embodiments, flow/velocity sensor **60** is placed toward the front section **14** of the mouthpiece **10** (e.g., near the front teeth), preferably in the center **15** of the front section **14**, so as to be in a location in the diver's mouth having the greatest velocity/flow rate (for example, at the peak of a velocity profile such as a velocity profile for Poiseuille flow). Such profiles can be determined using standard measurement methods known in the art for a standard mouth shape, size and tidal volume (or other related respiratory measurement), with adjustments made for a particular individual.

Communication device **100** can employ a variety of communication modalities including, for example, electromagnetic, RF, magnetic, optical, acoustical and/or combinations thereof. Referring now particularly to FIG. **10**, in the preferred embodiments, the communication device **100** can correspond to an ultrasonic or other acoustical transmission device **100***a* which transduces the electrical output signal **42** into an acoustic signal **101**, which is transmitted by the acoustical transmission device **100***a*. In such embodiments, communication devices **100** can comprise one or more acoustical transducers **105** which transmit and/or receive acoustical energy at a selected frequency or range of frequencies. Selected frequencies can be in the range of 10 to 40 kHz, 30 to 40 kHz, 100 to 200 kHz and 150 to 200 kHz. This frequency can be adjusted for one or more of the depth, salinity and temperature conditions of the water. Acoustical transducers **105** may correspond to one or more ultrasonic transducers **106**, which can comprise various piezo-electric materials, such as piezo-electric ceramic materials. The particular acoustical transducer **105** and acoustical frequency can be selected based on the desired acoustical transmission range, acoustical sensitivity, bandwidth, maximum diving depth, temperature and salinity conditions and related parameters.

Also, acoustical transducers **105** may be configured as both acoustical transmitters and receivers so as to send and receive acoustical signals. In many embodiments, transducers **105** can be arranged as an array **107** of transducers which may include a phased array formation. Array **107** can be configured to optimize one or more of the transmission range, sensitivity and bandwidth of communication device **100**. In various embodiments, the frequency, power settings and sensitivities of transducers **106** and/or array **107** can be selected to enable underwater transmission ranges for communication device **100** up to 1500 feet (457.2 meters) and more preferably, up to 2500 feet (762 meters) or even great transmission ranges. Also, communication device **100** can include signal generation and selection circuitry to allow for communication over multiple selectable acoustic frequency ranges, herein after channels. Communication device **100** may also include a multiplexing device (not shown for simplicity) coupled to at least one of the transceiver or signal processing circuitry so as to allow for the transmission and/or receiving of multiple signals. The multiplexing device may be configured for one or more of time division, frequency division or code division multiplexing. In alternative embodiments communication device **100** can comprise an RF based device and can even include RF communication chip **95** described above. In these and related embodiments, RF communication chip **95** is configured to have a selected power and frequency to enable underwater communication with other divers **210** and ship **220**.

Referring now to FIG. **11**, in many embodiments, communication device **100** can be incorporated into a portable watertight electronic (PWE) device **160**. PWE device **160** will typically comprise a PDA (Personal Digital Assistant) device or other similar device that is worn or carried by diver **200**. PWE device **160** may also comprise or be integrated into a dive watch, dive computer or other device or equipment carried by the diver, e.g., a flash light, depth gauge, regulator etc. For ease of discussion, PWE device **160** will now be referred to as a dive computer **160**; however, other embodiments are equally applicable. Dive computer **160** includes a processor **170**, display **180**, user input means **185** and an electrical power source **165**. Power source **165** may correspond to a portable battery such as a lithium or lithium ion battery or other batteries known in the art. User input means **185** may correspond to a touch screen which may be separate from or integral with display **180**. Processor **170** includes one or more modules **190** including software programs or other logics for controlling various operations of device **160** including those of communication device **100**. For example, in various embodiments, module **190** can comprise a program for discriminating between when the diver is speaking versus breathing using an output **61** from sensor **60** and then gate or attenuate microphone output **42** and/or transducer output **51** accordingly.

In other embodiments, module **190** can comprise a program or other logic instruction sets for generating and sending various voice commands and other voice messages **102** to the diver to alert them of various conditions and/or assist them in the performance of one or more tasks. In one embodiment, module **190** can comprise a program for the diver performing a controlled ascent whereby the program sends voice prompts to the diver telling them how long to remain at a particular depth before they can ascend to the next depth so as to avoid decompression sickness (also known as "the bends" or "divers' disease") or other related conditions. The program can be configured to send the prompts in response to one or more inputs such as those from an electronic depth gauge, electronic timer, SCUBA tank pressure or related gauge or sensor. Other inputs can include various messages from other divers **210** as well as the dive boat or other surface ships **220**.

The processor **170** will typically correspond to one or more microprocessors known in the art and can be selected for increased durability, fault tolerance and pressure resistance for underwater operation, using various military-specification (MIL-SPEC) criteria known in the military/naval equipment arts. Processor **170** will typically include one or more modules or algorithms **190** for generating, conditioning and controlling signals sent to and from the mouthpiece **10**, including signals **102** corresponding to voice messages as well as controlling other operations to allow two way voice communication by diver **200**. Modules **190** may also be configured for computing, monitoring and communicating various physiological data of the diver, including for example, heart rate, respiration rate, blood pressure, blood oxygen saturation and other blood gas measurements (e.g., blood nitrogen). Processor **170** may also include other modules **190** which use such data to determine if the diver is in a state of physiologic stress (e.g., such as stress caused by low blood oxygen levels, "hypoxia," or out gassing of nitrogen, "decompression sickness") or a precursor state which precedes or is otherwise predictive of a state of physiological stress. When such a stress state or precursor state of stress is detected, it may be communicated by the first communication device **100** to a second communicative device **110** to allow other individuals (such as those on the dive boat **220** or even those onshore) to monitor the diver(s) and alert them when it is time to ascend and/or if diver requires assistance.

In particular embodiments, PWE device **160** can comprise a dive computer or a related device that is carried or worn by the diver and is configured to provide the diver **200** various voice messages **102** (also referred to as spoken messages **102**) including alerts, prompts and commands using mouthpiece **10** and acoustic transducer **50**. This can be achieved through the use of processor **170**, audio signal generator **176**, and one or more modules **190** that are configured to generate and signal voice messages to the diver in response to one or more conditions and/or as part of a voice instruction set to the diver.

Referring to FIGS. **6***d* and **10**, in various embodiments, modules **190** can include a speech synthesizer module **191** which generates audio signals **51** corresponding to voices messages **102**. In use, such embodiments allow the diver to perform a number of tasks and activities, including various mission critical tasks without having the distraction of having to look at an instrument.

Speech synthesis module **191** can comprise various speech synthesis algorithms known in the art. Additionally in various embodiments, speech synthesis module **191** can include the capability for generating audio signals **52**, which correspond to a selected spoken voice **103**. Spoken voice **103** can include for example, the diver's own voice, or another person's voice similar that used in aircraft navigation and control systems. One or both of modules **190** and **191** can include the capability for the diver **100** to record specific messages **102** in their own voice or that of another individual to allow module **191** to output those messages to the another diver **210**. Further, modules **190** and **191** may also include the capability for the diver **200** to record a sufficient number of vocalizations (in their own voice or that of another individual) to allow module **191** to generate any spoken message **102** and not just those spoken by the diver **200** or other individual (e.g., the another diver **210**). The techniques for generating voices **103** from such vocalizations can include various algorithms known in the speech synthesis arts, for example, various concatenation routines **192** using stored speech units **193** derived from the speaker's (e.g., the diver's) vocalizations. Such routines can be embedded within the programming of module **191** or they may be external.

In an additional or alternative embodiment, modules **190** and **191** can also include the ability for the diver **200** to fine tune the voice **103** to have selected acoustic properties (e.g., pitch, volume, etc. to their liking). Such voice selection capability can be achieved by the use of one or more algorithms incorporated into module **191** such as a pitch variation algorithm **194**, rate variation algorithm **195** (and other adjustment algorithms known in the speech synthesis arts), which adjust audio signals **51** to produce the desired voice **103**. In use, such embodiments allow the diver **200** to select a voice that they are most comfortable with and can mostly easily hear, particularly underwater. In some embodiments, device **160** and modules **190**, and **191** can include the capability to allow the diver **200** to fine tune voice **103** while they are underwater with the mouthpiece **10** in place. Accordingly, in various embodiments device **160** can include various user input devices or other means **185** (e.g., knobs, touch screens, etc.) for making such adjustments.

In addition to manual adjustment of voice **103**, in various embodiments device **160** can also include means for varying the acoustical characteristics of voice **103** depending upon variations in one or more conditions experienced by the divers so as to maintain the divers ability to hear messages **102** spoken by voice **103**. Such conditions can include ambient noise levels, depth, water pressure and other like conditions. Accordingly modules **191** can include one or more control algorithms **196** (e.g., PI, PID, etc.) which operate using an input **197** which may comprise depth, pressure, ambient noise, etc. For the case of ambient noise levels, the input **197** can comprise signals **42** from microphone **42** or microphones coupled to device **160**. In use, such embodiments allow the diver to continue to hear commands **102** from voice **103** during changes in their depth and in ambient noises level (e.g., from a passing boat) which may otherwise drown out or reduce the acoustic fidelity of the voice. Module **191** can also adjust voice **103** as well depending on the particular type of SCUBA **80**, mask and mouthpiece used by the diver to account for variations in acoustical conduction and other acoustical characteristics.

Modules **191** can also be configured to modulate or otherwise adjust voice **103** to account for reduced levels of conduction by bone of higher acoustic frequencies. This can be accomplished for example through the use of pitch variations routines **195** which shifts the pitch of all or a portion of the frequency components of voice **103** to lower frequencies (e.g., make voice **103** deeper). In an additional approach for improving conduction through the bone of the higher frequency components of voice message **102** or other acoustic signals **52** various embodiments of the invention may use high pass signal routines implemented in hardware (e.g., a high pass filter coupled to op amp device) or in software by a module **198** running on one or both of processor **170** and **70**. Such an approach (either in hardware or software) amplifies the higher frequency components of voice **103** or other acoustic signal **52** by a selected gain which can vary depending upon the frequency (e.g., more gain for higher frequencies). In one approach, the amount of the gain can be determined by doing sound conduction readings through the diver's skull and/or taking bone density readings using one or more bone densitometer instruments known in the art.

Device **160** can send signals **51** to mouthpiece **10** using a variety of modalities. For example, in various embodiments, device **160** can send audio signals **51** containing modulating or otherwise encoding a voice message **102** to mouthpiece **10** via wires **17**, or alternatively may do so wireless using an RF other wireless communication device **96**. In another embodiment, a second device **160'** not directly coupled to mouthpiece **10** can be used to acoustically signal voice messages **102** to device **160** which is operatively coupled to mouthpiece **10** either via wires **17** or through use of RF communication devices **95** and **96**.

As described above, various embodiments of the invention which generate spoken messages **102**, for example using device **160**, allow the diver to perform a number of tasks and activities, including various mission critical tasks without having the distraction of having to look at gauge or other instrument. Further, messages **102** can include not just data such as depth, remaining air, etc., but can include prompts for performing one or more operations or tasks. For example, in one or more embodiments, messages **102** can include spoken directions for reaching a desired location, such as a dive site, or the location of a dive boat or that of other divers. Specific commands in such embodiments can include without limitation, "swim up," "swim down," "bear to the right," "bear to the left,". This allows the diver to navigate to such locations while looking at their surrounding and/or when there is minimal lighting.

In one or more exemplary embodiments, dive computer **160** and communication system **5** can be configured to provide the diver **200** with voice messages **102** in the form of prompts for making a controlled ascent to the surface as to avoid the bends. Specifically, the dive computer could provide voice prompts telling the diver one or more of how long to remain at a particular depth during the ascent, what depth he is at, how long he has been at the depth and how soon before he can ascend to the next depth. The computer could also provide the diver with voice updates providing information such as their ascent rate and whether they need to stay longer or shorter at a particular depth depending on conditions. In addition to prompts and updates, the dive computer may also provide voice instructions of the entire ascent plan in advance allowing the diver to get a sense of the entire plan.

While in many embodiments, mouthpiece **10** is configured for use with a SCUBA **80**, in other embodiments, the mouthpiece can also be configured for used with a snorkel or like apparatus, allowing a snorkeler to have two way voice communication with another snorkeler, diver **210** or ship **220**. In such embodiments, the entire system **5**, including communication device **100** can be contained in the mouthpiece **10**. Further, in such embodiments, the connecting portion **11** can be sized and shaped to detachably connect to a standard sized snorkel, allowing the diver to attach the mouthpiece **10** to an off the shelf commercial snorkel and have a skin diving version of underwater communication system **5**. In still other embodiments, mouthpiece **10** and system **5** can be adapted for use with virtually any breathing apparatus such as that used by fire and mine rescue personal, so as to allow two way voice communications with such apparatus.

Referring to the embodiment in FIG. **12**, a speech enhancement system **1202** may be provided with or as an integrated part of an underwater breathing apparatus **1200**. Accordingly, a combined system of speech enhancement **1202** and underwater breathing apparatus **1200** can be devised in form of a scuba mask, mouthpiece, and/or add-on accessory.

In one embodiment, the underwater breathing apparatus **1200** includes a mouthpiece (for supplying oxygen) and mask (not shown). The apparatus **1200** may be integrated or combined with the speech enhancement system **1202**. Speech enhancement system **1202** includes voice input mechanism **1210**, speech enhancement hardware **1220**, and voice output mechanism **1230**. The input mechanism **1210** may correspond to a microphone, that is carried with the mask, mouthpiece or tubing. The input mechanism **1210** carries unprocessed voice input **1212** to the speech hardware **1220**. The speech hardware **1220** can include programming and/or logic to process the voice input **1212**.

In an underwater operational environment, voice input **1212** can be assumed to be hindered by factors such as the presence of the mouthpiece and/or other aspects of breathing using an underwater breathing device such as a SCUBA. Additionally, the user may be under physical stress or out of breath. In at least one implementation, speech enhancement hardware **1220** includes a processor coupled to the input mechanism. Speech enhancement hardware **1220** is configured to process a hindered voice input from the user.

Still further, in some embodiments, the speech hardware **1220** includes software or programming (e.g. a module) to recognize speech in its hindered form, and further to generate output that corresponds to a corrected or clarified version of the speech input. More specifically, the processor determines (or makes a probabilistic determination, i.e., a guess) at what the user is intending to say. The processor then signals a voice output **1222** that corresponds to corrected or clarified voice output (e.g. unhindered simulated or synthesized speech).

A voice output mechanism **1230** may receive the processed output **1222** of the speech hardware resources **1220**. The output **1222** may be transmitted to the output mechanism **1230**, which may reside outside of the diver's presence. For example, the output mechanism **1230** may be positioned with one or more other divers, surface ships, or to an underwater electronic device which generates voice messages for the diver.

In some implementations, the speech enhancement hardware **1220** includes one or more software modules that execute on processing resources (e.g., a microprocessor) of speech enhancement hardware **1220**. The modules may be configured to facilitate performance of the system, such as production of voice output. Specific embodiments of speech enhancement hardware **1220** may include routines for recognizing input sounds (e.g., phonemes, consonants, etc.) or even whole words which may become garbled, slurred or otherwise incomprehensible, due e.g., the diver speaking with the breathing apparatus in place; matching those input sounds to voice output sounds; and then, generating a voice output based on those voice output sounds.

Voice output **1222** is produced by speech enhancement hardware **1220** and may constitute any appropriate form in context of speech enhancement system **1220**. For example, in various embodiments the voice output **1222** may include an underwater signal to a receiver, electrical output, or a "blended" output comprising at least some of the voice input **1212** and synthesized or simulated portions. The voice output can be in the speaker's own voice (simulated), a synthesized voice or a combination thereof. The former can be implemented by having the speaker record a library of speech sounds (also known as phonemes) including consonants, vowels, diphthongs, prefixes (e.g., "pre"), and suffixes (e.g. "ing"). Furthermore, in various embodiments of methods for matching voice input to voice output, the diver can record pronunciation of each sound with and without the mouthpiece in place.

FIG. **13** illustrates an embodiment of speech enhancement comprising receiving voice input **1310**, recognizing voice input speech **1320** and production of voice output **1330**. The voice input **1310** may include hindered speech. Hindered speech includes speech that is garbled, slurred, impeded or otherwise made incomprehensible by the presence of an underwater breathing apparatus. Voice input recognition **1320** may be performed in a variety of ways, including those recited in the shown sub-steps of FIG. **13**. For example, in Step **1322** (Word/Phrase Matching), a limited vocabulary may be preloaded. Also, speech recognition in Step **1322** may comprise recognizing speech based on context, partial sounds, or other corresponding features of the input speech which, in some embodiments, may be associated with the preloaded vocabulary. As an alternative or addition, Step **1320** may further comprise additional steps **1324** (e.g., use of a phoneme library) or waveform analysis **1326**. Recognizing the voice input may further comprise assigning similarity factors for each characteristic, e.g., cadence 95% similar, volume 98% similar so that appropriate adjustments can be made for matching each characteristic. These characteristics can be weighted and combined into a composite characteristic with a composite similarity factor assigned as well. Such adjustments are particularly applicable for embodiments of the module utilizing a buffer to store the diver's speech, detect and process voice input to voice output and then blend the voice output into the voice input.

In an embodiment, for each recording of the input speech, the module generates and stores an audio signal waveform. The module can then use waveform/pattern recognition routines to identify that waveform and match it to a voice output. In such an embodiment, the diver may make several pronunciations for each sound so that the module can take an average of the voice input waveforms. For embodiments where the module uses waveform analysis, various curve fitting algorithms can be used to determine an overall fit between a sampled sound and a known input sound (e.g., a hindered input "th" sound corresponding to a known output "th" sound). Such an approach allows for improved accuracy in matching a voice input to a voice output. Further, the module may also include algorithms which adjust or otherwise take into account for the pressure and gas mixture that the diver is breathing (or other dive or breathing condition) together which may affect the waveform of the voice input.

Voice output step **1330** may include a variety of sub-steps, including the production of an underwater signal to a receiver as in Step **1332**, electrical output as in Step **1334**, or blended output as in Step **1336**. Step **1336** may comprise the voice output including at least some of the voice input speech ("blending"). For example, where System **1300** includes memory caches or a buffer, Step **1336** may comprise storing the diver's voice input, substituting in the voice output sounds where appropriate and playing back the blended speech as a whole so that the listener does not hear any breaks in the diver's spoken messages. For example, a software module could be included in order to remove or otherwise minimize any pauses in the voice output so that the blended speech sounds continuous to the listener. In performing such an operation the module can take a sampling of the diver's speech to determine the average interval between words and then use that to look for gaps which are larger than the average interval. In an embodiment, system **1330** further includes routines for matching one or more characteristics of the voice output e.g., **1230**, to the voice input e.g., **1212** so that the differences between the two are not readily discernible to the listener. Such characteristics can include without limitation the cadence or speed of the speech, pitch of the speech, volume of the speech (amplitude) or other related property.

The foregoing description of various embodiments of the invention has been presented for purposes of illustration and description. It is not intended to limit the invention to the precise forms disclosed. Many modifications, variations and refinements will be apparent to practitioners skilled in the art. For example, various embodiments of the communication system **5** including the mouthpiece **10** can be adapted for salt and fresh water environments, as well as deep dives (e.g., 60 to 200 meters (196.9 to 656.2 feet)) and cold water environments. They may also be adapted for use in closed circuit re-breathers in addition to standard SCUBA equipment.

Elements, characteristics, or acts from one embodiment can be readily recombined or substituted with one or more elements, characteristics or acts from other embodiments to form numerous additional embodiments within the scope of the invention. Moreover, elements that are shown or described as being combined with other elements, can, in various embodiments, exist as standalone elements. Hence, the scope of the present invention is not limited to the specifics of the described embodiments, but is instead limited solely by the appended claims.

What is claimed is:

1. A system for enhancing speech, the system comprising:

an input mechanism to receive a first voice input from a first user;

a communication device to transmit and receive acoustic signals across a liquid medium and to generate an electrical signal based on received acoustic signals;

a transducer to convert the electrical signal into an acoustic output;

wherein the transducer is configured to be coupled to the first user's upper teeth to generate audible sound in at least one of user's ears;

and

a processor configured to:

receive the first voice input from the first user;

recognize speech of the first user based on the first voice input; and

output a respective acoustic vocal signal to the communication device based on the speech.

2. The system of claim **1**, wherein the first voice input is a hindered voice from the first user wearing an underwater breathing apparatus.

3. The system of claim **2**, wherein the underwater breathing apparatus comprises the input mechanism.

4. The system of claim **3**, further comprising a self-contained underwater breathing apparatus (SCUBA), and wherein the underwater breathing apparatus is coupled to the SCUBA.

5. The system of claim **1**, wherein the transducer is configured to conduct the acoustic output from the first user's upper teeth through the first user's skull to generate the audible sound, and wherein the communication device is further to process the electrical signal to increase conduction of the acoustic output at higher frequency levels.

6. The system of claim **1**, wherein the received acoustic signals correspond to a second voice input from a second user.

7. The system of claim **1**, wherein the processor is further configured to provide the respective acoustic vocal signal output in a synthesized voice.

8. The system of claim **7**, wherein the processor is further configured to supplement the first voice input with a synthesized input to generate a composite audio output signal so as to provide the respective acoustic vocal signal output in the synthesized voice.

9. The system of claim **8**, wherein the synthesized voice is selectable to vary in pitch or volume in response to an input.

10. The system of claim **9**, wherein the input comprises a diving depth, ambient noise level, air supply gas mixture, air supply amount, air supply pressure, air supply flow rate, or rate of ascent by a diver.

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